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INFORMATION RESOURCE - WATER POLLUTION CONTROL IN
WATER UTILITIES

AMERICAN WATER WORKS ASSOCIATION RESEARCH FOUNDATION

PREPARED FOR
ENVIRONMENTAL PROTECTION AGENCY

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WATER POLLUTION CONTROL
IN
WATER UTILITIES

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Grant S800936
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This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names of commercial products constitute endorsement or recommendation for use.

ABSTRACT

The goals of this effort were the collection, coordination, and communication of information of a scientific, technical, and administrative nature relative to control of pollution caused by wastes from water treatment plants, in accordance with the recommendations of an industry advisory committee.

It covers laboratory tests underway or completed at widely dispersed water treatment plants throughout the country on the applicability of polymers as primary coagulants, coagulant aids, and sludge conditioning agents, with the objective of alleviating the problem of water treatment plant waste disposal. Also included is the evaluation in cooperating laboratories of analytical methods suitable for the physical and chemical examination of the sludge and sludge solids from water treatment plants.

A total of 121 abstracts of technical articles were prepared on the varied aspects of water treatment plant waste disposal: waste problems at 26 named water treatment plants or geographical locations, waste treatment in the new water treatment plants, water conditioning practices, characteristics of alum, iron, and softening wastes; treatment of filter washwater; treatment of sludge by the reclamation of alum, lime, and magnesium carbonate, and by dewatering processes involving centrifugation, drying beds, filter pressing, freezing, and vacuum filtration; subsurface disposal and disposal of brine wastes.

This report was submitted in fulfillment of Project 12120 EUR under the partial sponsorship of the Environmental Protection Agency, in cooperation with the American Water Works Association Research Foundation.

Information concerning this project can be obtained from the author: The American Water Works Association Research Foundation, 2 Park Avenue, New York, N. Y. 10016.

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SECTION I

CONCLUSIONS

Need to Meet Waste Guidelines

The Water Pollution Control Act Amendments of 1972 authorize the establishment of guidelines for all industrial discharges, including those from the water utility industry. The attainment of the national guidelines is envisioned as encompassing three well defined stages. Industrial discharges must achieve as a minimum the best practicable control technology by July 1, 1977, and the best available control technology not later than July 1, 1983. The elimination of pollutant discharges by 1985 is a national goal, with stream quality adequate for the support of fish and wildlife by 1983 as an interim goal.

AWWA Research Foundation Contributions

Anticipation of this development prompted the American Water Works Association Research Foundation in 1968 to begin collecting, coordinating, and communicating the technical information which will enable the water utility industry to fulfill its responsibilities with respect to the new guidelines. This work was partially supported by grants from the Federal Water Pollution Control Administration and the Environmental Protection Agency. The Research Foundation has investigated all known technological processes which are currently available or under development, and identified the areas still requiring further study and research. The complete findings in these matters are detailed in two project reports issued in 1969 and 1971.

Waste Reclamation

New treatment plants often embody facilities for recapturing and recycling filter washwater, both to minimize the waste disposal problem and to secure the benefits of improved coagulation with a possible reduction in coagulant dosage.

Logic dictates that the reclamation of water treatment chemicals such as alum, lime, and magnesium carbonate will eventually prevail in many locations, as the long term solution to the waste disposal problem. Reclamation will be required because the earth's resources are finite. However, the necessary recycling facilities are still under development and refinement, due to past neglect of this aspect of the problem. The economics of by-product recovery are continually improving by virtue of the escalating costs of transporting and handling solid materials. Accordingly, the movement of waste to distant landfills is losing its former competitive advantage over recycling and recovery processes.

Short and Long Term Solutions

Although reclamation facilities can be readily incorporated in new water treatment plants during the design or construction stage, corrective measures will be needed for plants now in operation. Unfortunately, no single all-embracing technology is suitable for solving the short term and long term waste disposal problem in every instance. The unit processes suitable for remedial applications include in-plant treatments such as sedimentation tanks, concentrator chambers, settlement and thickening tanks, and chemical conditioning; and mechanical dewatering devices such as centrifuges, filter presses, vacuum filters, and draining and drying beds. Other disposal practices involve dilution, sludge pumping, discharge to sanitary sewers or lagoons, freeze-thaw, and land disposal. All of these approaches have been successfully demonstrated at various installations. The economics and demands of the local situation will govern which process will be adopted for the short, intermediate, and long term solution.

Polymer Coagulants

Supplementing the mechanical equipment needed to ensure compliance with eventual guidelines, widespread investigations have been undertaken by the water utility industry and chemical suppliers. Investigations include studies of primary coagulants and coagulant aids which can minimize dependence on the common inorganic coagulants, alum and iron salts. Polymers offer a hopeful prospect for replacing inorganic coagulants, reducing coagulant quantities needed for the clarification process, and for conditioning the resultant sludge for easier disposal. This class of substances may provide a short and/or long term answer in the proper circumstances.

Ultimate Disposal

The most challenging problem in the control of wastes from treatment plants is the disposition of the unwanted final product. There is a limit on the amount of material that can be conserved and reclaimed. A small quantity of presently unmarketable and useless residue remains at the end of most recovery processes. Old plants lacking reclamation facilities generate appreciable amounts of solid waste that often must be hauled at considerable cost to remote sites. Landfill and underground disposal, together with barging to sea, are the practices most frequently utilized for ultimate disposal of residual wastes.

SECTION II

RECOMMENDATIONS

Compliance with Waste Guidelines

The American Water Works Association Research Foundation provides a valuable vehicle for attainment of the quality guidelines authorized by the Federal Water Pollution Control Act Amendments of 1972. The eventual aim of zero discharge of pollutants and total environmental control embracing water, solids, and air will be achieved by the continual improvement of the water treatment processes as well as the addition of the proper waste treatment facilities.

The task assumes considerable proportions because an appreciable number of water treatment plants are unequipped to meet the proposed standards. The absence of prior legal compulsion to treat water plant wastes, coupled with the failure to anticipate the need by the installation of the necessary equipment during the original construction, are at the bottom of the difficulty.

Present Technology for Meeting Guidelines

The American Water Works Association Research Foundation program of collecting, coordinating, and communicating information of a scientific, technical, and administrative nature relative to the control of pollution caused by wastes from water treatment plants is the most effective way of achieving this objective. A significant body of knowledge has been assembled by the Research Foundation with respect to the relative utility of the processes available for the treatment, reclamation, and disposal of water treatment plant wastes.

Dewatering of sludge can be accomplished by the use of centrifugation, chemical and polymer conditioning, drying beds, filter pressing, freezing, lagooning, sedimentation, thickening, and vacuum and precoat filtration. A survey of the equipment fabricated by more than 100 manufacturers is needed on the products designed to dewater sludge or treat water plant wastes. This information will prove invaluable to utilities operating old plants currently in violation of pollution regulations.

Recovery processes are available for treatment chemicals such as alum, brine, lime, and magnesium carbonate. Reclamation is an attractive concept which is destined to command increasing attention because of the minimal discharge of pollutants to the environment. The adoption of reclamation processes in new and old installations should be promoted wherever possible.

Polymers afford a promising field of investigation by virtue of the reduction in the sludge volume which they can effect through replacement or supplementation of common coagulants such as alum and iron salts. The fact that polymers can be custom tailored for a particular water supply offers hope for the development of a sufficient number with useful properties. Laboratory tests of polymers are now underway as a part of studies conducted by the Research Foundation in widely dispersed water treatment plants throughout the country. These tests will evaluate the applicability of polymers as primary coagulants, coagulant aids, and sludge conditioning agents. The results of these tests must be evaluated, and expanded studies may be required.

Future requirements

All technology is subject to improvement from the standpoint of economics and material effectiveness. The ideal development would be a single, inexpensive, and easily processed coagulant to fit all water treatment situations. Since the world is not tailored of such simple cloth, unremitting research is needed into new chemical and treatment methods.

The reclamation and recycling of chemicals, and the application of polymers as primary coagulants, coagulant aids, and sludge conditioning agents afford possible solutions to the waste disposal problem and should be subjected to intensive investigation.

Landfill and underground disposal, together with barging to sea should be investigated further to learn their advantages versus their shortcomings as methods of ultimate disposal.

The control of waste discharges underscores the need and importance of developing a standard methodology for the sampling and analysis of sludge and sludge solids. Such methods are needed for the reliable measurement of the effectiveness of current and future treatment processes. The presently available analytical methods for the physical and chemical examination of sludge and sludge solids require further evaluation in cooperating laboratories before general acceptance can be assured.

The AWWA Research Foundation will promote and contribute to the development of research in these and similar areas. As a clearinghouse for information, the Foundation will serve to transfer the new technology to the water utility industry as promptly and as effectively as possible.

SECTION III

INTRODUCTION

Recent national legislation spells out the evolutionary stages of the water pollution control program. Wastes from the water utility industry come within the jurisdiction of this legislation.

Although new water plants can be designed with adequate facilities to meet the legislated requirements, old plants may have difficulty accommodating to the effluent standards. These problems were foreseen during the creation of the American Water Works Association Research Foundation and one of the first research projects to be undertaken was the problem of coping with water treatment plant wastes. This study was supported in part by a grant from the Federal Water Pollution Control Administration and embraced known treatment technology, cost data, and suggestions for future needs. The project findings were incorporated in the report entitled "Disposal of Wastes from Water Treatment Plants" published in 1969. The report urged the establishment of a central information clearing-house to organize, coordinate, and disseminate information on new or modified treatment technology and promote its application by the water utility industry.

A grant from the Water Quality Office of the Environmental Protection Agency, together with matching funds from 30 water utilities, enabled the fulfillment of this recommendation. A project advisory committee, composed of experts actively engaged in the research, engineering, plant operation, and regulatory aspects of the sludge disposal problem, was assembled for a two-day meeting. The committee members were encouraged to exchange ideas and offer suggestions for the organization of an information service.

Implementation of their recommendations has resulted in the accumulation and dissemination of current research information and criteria of value in the solution of specific problems at individual water utilities.

A search of the pertinent literature has revealed the research and development activities underway in government agencies, water research institutions, and the water utility industry. A substantial number of technical articles have been abstracted in accordance with Water Resources Science Information Center specifications for inclusion in their computerized storage and retrieval system.

Surveys were undertaken among regulatory agencies and water treatment plants. The findings of the regulatory surveys provided new insights into treatment requirements, acceptability of sludge disposal methods, maintenance and reporting of waste production records, and the support and conduct of research. The water utility surveys underscored a need for standard methods for sampling, examining, and categorizing waste materials from water treatment plants. A subcommittee was appointed to develop such laboratory methods applicable to all types of water treatment plant wastes.

A polymer evaluation program was also initiated to determine the applicability of polymers as primary coagulants, coagulant aids, and sludge conditioning agents.

The publication of this information should stimulate further research into these important sectors.

The project advisory committee concluded that there is no single universally acceptable treatment for conventional and softening sludges, and that a variety of treatment alternatives will require evaluation on a local basis wherein efficiency, operation and maintenance requirements, and economics will play their proper roles.

This synopsis can only touch upon the highlights of the two previous reports on this project published in 1969 and 1971. The original reports must be consulted for background details, and, in fact, must be considered the foreword to this report.

Copies of earlier reports referred to are available:

- (1) "Disposal of Wastes from Water Treatment Plants" -- 1969 Report, 78 pages. Reprint from the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION, available from the American Water Works Association Research Foundation, 2 Park Ave., New York, N.Y. 10016.
- (2) "Information Resource: Water Pollution Control in the Water Utility Industry" -- 1971 Report, 169 pages. U.S. Environmental Protection Agency, Water Pollution Control Research Series, 12120 EUR, 11/71. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, Price \$1.50.

SECTION IV

INFORMATION RESOURCE ACTIVITIES

The water utility industry of the United States needs direction and guidance in controlling waste discharges from water treatment plants. The American Water Works Association Research Foundation provides the mechanism for collecting, synthesizing, and disseminating information designed to promote the efficient development and application of technology for pollution control by the water utility industry. These objectives are accomplished by the collection and transfer of technical data on disposal of water treatment plant wastes, the compilation of abstracts and indexes of the pertinent technical literature, and by special studies of new technology.

Research Foundation Clearinghouse

The clearinghouse function conducted by the Research Foundation consists of gathering and classifying all information on research, demonstration, and plant scale projects completed, in progress, or projected. Important parts of this effort include:

Updating of cost data, the accumulation of basic data on the quality and quantity characteristics of waters from water treatment processes, and studies of their polluttional effects.

Determination of immediate and long-range needs for basic and applied studies, and for plant scale demonstration projects.

The assembled information is coordinated, analyzed, and translated into a form that facilitates its application in research and demonstration projects.

A Project Advisory Committee, representing a variety of scientific, engineering, and administrative disciplines, assists in the development and analysis of the most useful data.

One purpose of these activities is to encourage cooperation between investigators in educational institutions, governmental agencies, and water utilities. Another aim is to acquaint academic researchers with practical applications so that their investigations can be designed to achieve maximum benefit.

The ultimate goal is the development of effective and economical methods for the treatment and final disposal of the substantial quantities of solid wastes emanating from the water utility industry. The offending wastes include those from filter backwash and ion exchange brines, and from the coagulation, softening, iron and manganese removal, diatomaceous earth filtration, and desalting processes.

Transfer of Information

Efficient and speedy communication of information is essential to keep the research sector conversant with current projects and problems, and to advise the water utility industry regarding new developments in the disposal of wastes from water treatment plants.

As a central resource for organization and coordination, the Research Foundation conducts extensive correspondence with scientists, engineers, administrators, and manufacturers in the United States and abroad on the subject of new information and improved technology for the disposal of wastes from water treatment plants. Periodic articles are published in technical journals and progress reports are delivered at meetings of AWWA Sections.

Since its inception, the Research Foundation clearinghouse has initiated and maintains contact with a total of 740 individuals in the following organizations and specialized technical categories:

- Chemical Suppliers
- Consulting Engineers
- Educational Institutions
- Equipment Manufacturers
- Governmental Agencies
- Municipal Water Utilities
- Science Information Exchange
- State Water Resources Research Institutes
- Foreign Institutions and Agencies, including
the British Water Research Association and
the International Water Supply Association

Numerous inquiries by phone and letter are answered from these and other interested individuals during the course of the year. The availability of these services have been publicized in the JOURNAL AWWA, WILLING WATER, NEWSLETTER, and in trade publications.

Technical Developments Underway

In addition to the material gathered through literature searches, valuable unpublished information has been accumulated by correspondence and personal contact with individuals who are conducting applied research. Significant work of this nature is being performed by consulting organizations which are engaged in comprehensive laboratory, pilot plant, and full plant-scale studies.

The following processes and equipment for treating and dewatering water plant wastes are being subjected to such evaluation: chemical coagulation, freeze and thaw by continuous mechanical means, centrifugation with basket and solid bowl of raw sludge and chemically treated sludge, filter pressing of both raw and chemically treated sludge and vacuum filtration of both raw and chemically treated sludge.

Consulting firms are also investigating the build-up of color, turbidity, heavy metals, and other constituents which results from the use of acid-recovered alum in water treatment.

The abstracts and the original papers and articles in the Research Foundation files are a valuable resource to engineers and researchers active in the waste disposal field. Considerable time is saved in literature searching by reference to the two previous project reports and the continually updated abstract file. Papers, published and unpublished, by foreign authors hold a special attraction because of their limited availability in this country.

Distribution of Reports

All of the studies completed since the inception of the project in 1968 are delineated in two reports prepared by the Research Foundation, each of which has had a circulation in excess of 1,000 copies. At the request of the Environmental Protection Agency, the Research Foundation has also distributed to its specialized mailing list reports on the actively supported project involving the application of magnesium carbonate as a recycled coagulant.

The total distribution of these reports is presented in the following table:

TABLE 1

Distribution of Reports

<u>Copies Mailed</u>	<u>Title of Report</u>
1100	"Disposal of Wastes from Water Treatment Plants". Water Pollution Control Research Series. 12120 ERC (August 1969).
1025	"Information Resource: Water Pollution Control in the Water Utility Industry". Water Pollution Control Research Series. 12120 EUR 11/71.
840	"Magnesium Carbonate, A Recycled Coagulant for Water Treatment". Water Pollution Control Research Series. 12120 ESW 06/71

Reports at Technical Meetings

Papers on the disposal of wastes from water treatment plants were delivered by the Research Director at meetings of AWWA Sections in Illinois, Iowa, Ontario, and Pennsylvania, as well as at the 1972 AWWA Conference. Five technical papers on the disposal of water treatment plant wastes were a feature of the Water Quality Division session at the 1972 AWWA Conference held in Chicago.

A discussion on the disposal of alum sludge wastes from water treatment plants in the U.S.A. and the activities of the AWWA Research Foundation was presented by the Research Director at the Ninth International Water Supply Congress and Exhibition on September 14, 1972 in New York City.

JOURNAL AWWA Issues

During 1972 the Research Foundation played a principal role in compiling two full issues of the JOURNAL AWWA. The October issue dealt with the general area of water treatment research, including the disposal of plant wastes. The November issue encompassed all phases of desalination including waste disposal. A third issue scheduled for publication during the summer of 1973 will focus on water treatment plant sludge and contain the papers presented at the 1972 AWWA Conference in Chicago together with additional germane contributions.

Project Relation to EPA

The Research Foundation has also been invited to assist the Engineering and Sciences staff of the Environmental Protection Agency located in Cincinnati, in the preparation of effluent guidelines for water treatment plant wastes. The objective will be the formulation of guidelines on a progressively restrictive basis from the current average results to zero discharge as specified in recently enacted national legislation.

The Research Foundation's continuing study of water treatment plant waste disposal was deemed relevant in reviewing the over-all problem, determining the need for research and demonstration, investigating the achievement of current waste treatment plants, and establishing monitoring procedures for waste discharges.

SECTION V

TECHNOLOGY TRANSFER

Research currently conducted on the disposal of wastes from water treatment plants is, unfortunately, not in proportion to the magnitude of the problem. The number of ongoing investigations in academic institutions and water utilities, and conducted or supported by governmental agencies, is relatively small. Much of the research completed or underway is directed toward the removal of water from sludges, and little research has been directed to problems of ultimate disposal.

In keeping with its objective to explore acceptable ways of alleviating the sludge disposal problem, the AWWA Research Foundation has contributed support to the pilot plant study and currently the plant scale study at Montgomery, Alabama, involving the use of magnesium carbonate as a recycled coagulant for water treatment. The process displaces filter alum and enables the repeated use of magnesium carbonate and lime once the proper processing facilities have been installed and placed in operation. Favorable results on a plant level will justify extending trials to other plants around the country. The Research Foundation will encourage this effort and publicize the operational data when they become available.

During February 18-21, 1973, a Research Foundation staff member traveled to Montgomery, Alabama to participate in a three-day seminar-workshop on the magnesium carbonate water treatment system. The lectures were delivered on the campus of Auburn University of Montgomery, and the demonstrations were conducted at the Montgomery water treatment plant. The Montgomery project is jointly supported by the Environmental Protection Agency, the City of Montgomery, and the AWWA Research Foundation.

The lectures explored the problems created by water treatment plant sludge and the views of regulatory agencies with respect to polluting discharges, the history and basic concepts of the magnesium carbonate system. Presentations included flow diagrams, pertinent chemical reactions, preliminary laboratory studies, and the economic optimization of the process. A computerized evaluation was offered on the cost of the various unit operations alongside of the actual costs. Emphasis was placed on the applicability and advantages of the magnesium carbonate system for turbidity and color removal, softening, and the recovery of magnesium, lime, and carbon dioxide in both new and old installations.

Two visits were made to the Montgomery water treatment plant for an inspection of the facilities required by the magnesium carbonate recycling system and the concomittant laboratory and plant controls. Special attention was directed to the magnesium recovery and dewatering operations involving carbonation cells, thickener, vacuum filtration, and sand drying bed.

The following advantages of the magnesium carbonate system were cited by Dr. A.P. Black at the conclusion of the seminar-workshop:

The coagulant can be recycled and reused, thereby providing an economical and practical solution to the sludge disposal problem, concurrently with a reduction in chemical treatment costs.

The increased settling rate of the magnesium hydroxide and calcium carbonate floc enables a higher clarifier loading rate and an improvement in the filtrability of the settled water.

The finished water is noncorrosive and stabilized by pH control.

The 11.2 - 11.5 pH range used to produce the magnesium hydroxide floc inactivates most viruses and destroys bacteria, thus minimizing the need for prechlorination.

The system is simple to operate and automate, and entails no important physical changes in existing treatment plants.

Hard waters provide an opportunity to reduce operating costs through lime recalcination and the production of magnesium carbonate from the sludge for external sale.

The Research Foundation has recently assisted Dr. Black in his efforts to publicize the advantages of the magnesium carbonate coagulant process. He has been provided with the names and addresses of the responsible officials in 33 water departments throughout the nation. These officials will be invited to attend a meeting designed to expand the availability of technical information on the process.

The AWWA Research Foundation has supplied pertinent information to a public water utility which is contemplating the recalcination of its softening sludge. A copy of Dr. Black's publication **MAGNESIUM CARBONATE, A RECYCLED COAGULANT FOR WATER TREATMENT** was also forwarded to the utility for consideration of the new process as an alternative to recalcination. The magnesium carbonate technology appeared applicable in the circumstances and deserved serious study as an all-embracing water treatment for that supply.

Dr. A.P. Black's report entitled "Magnesium Carbonate, A Recycled Coagulant For Water Treatment," Water Pollution Control Research Series, Project 12120 ESW, 06/71, is available at a cost of \$1.00 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

SECTION VI

POLYMER EVALUATION PROGRAM

The favorable prospects for application of polymers in water treatment are succinctly enumerated in the Report of the AWWA Water Quality Division Committee on "Disposal of Water Treatment Plant Wastes", published on pages 814-820 of the December 1972 issue of the JOURNAL AWWA.

The following excerpts from the report describe the multiple advantages of the polymers with respect to the disposal of water treatment wastes:

"With the new and improved organic polymers available today it may be possible to reduce or even eliminate the use of alum or similar coagulants used for water clarification. In some instances, where raw water quality permits, the application of minute dosages (10 to 30 parts per billion) of a polyelectrolyte to the filter influent water may suffice to produce a good quality of filtered water without the need for prior coagulation. In others, where coagulation is necessary, very few dosages (0.2 to 3 parts per million) of the proper polyelectrolytes may effectively take the place of much larger dosages of alum (or similar chemicals) as the primary coagulant.

Substitution of polyelectrolytes for the more commonly used coagulants would not only reduce the quantity of sludge developed but would also produce a sludge more amenable to dewatering or other processing for reduction in volume. The sludge would also be more suitable for incineration as a result of the substitution of organics for the non-combustible inorganic coagulants. An additional benefit could be reduction in cost of chemicals for treatment as the substantial reduction in dosages required may offset the higher unit cost of polyelectrolytes"

The value of polymers as flocculants and coagulant aids in the water treatment field was emphasized at the International Water Supply Association Congress and Exhibition held on September 14, 1972 in New York City. The consensus based on European experience was that polymers definitely warrant continuing study.

Although polymers admittedly do not represent a panacea for all the problems besetting water treatment, they may provide an answer in some localities. The incidence of success and failure, and the advantages and limitations should be ascertained before a general assessment is attempted. The first logical step in such a direction is a laboratory evaluation program which encompasses varied water supplies throughout the country, and is based on an accepted standard jar test procedure.

The AWWA Research Foundation has developed a program of laboratory evaluations, now underway in such widely dispersed geographical regions as the eastern seaboard, the midcontinent, and the far west. The eleven

laboratories are evaluating a total of 46 polymers supplied by eleven manufacturers, consisting of primary coagulants, coagulant aids, and sludge conditioning agents. The specific polymers under test are identified in Table 2. Each of the ten water department laboratories in the project are evaluating eight to fifteen polymers in the treatment of their own water supply, with the average number approximating ten polymers.

Since the commencement of the evaluation program, significant operator interest has been evidenced in polymers capable of functioning as primary coagulants. The major manufacturers are endeavoring to supply this demand with a maximum research and development effort in this direction. The Research Foundation has arranged to distribute the emerging and as yet unmarketed products for laboratory evaluation among interested operators. Such a procedure should benefit both suppliers and operators by identifying the polymers with the broadest potential prior to their formal commercial introduction.

A questionnaire mailed to each participant relative to the beginning and completion dates of their laboratory tests suggests that the final results might realistically be expected about the summer of 1973. The data submitted to the Research Foundation on prepared forms will be tabulated, summarized, and interpreted. The useful findings emerging from the project will be publicized in the professional journals as a contribution to the adoption of this new technology.

TABLE 2

Polymer Products Under Evaluation

By AWWA Research Foundation

American Cyanamid Co.

Magnifloc 521C
Magnifloc 570C
Magnifloc 845A
Magnifloc 860A
Magnifloc 972N
Magnifloc 985N
Magnifloc 990N

Betz Laboratories

Poly-Floc 1100
Poly-Floc 1110
Poly-Floc 1120
Poly-Floc 1130
Poly-Floc 1150
Poly-Floc 1160
Poly-Floc 1175
Poly-Floc DK-483

Burtonite Co.

Burtonite #78

Calgon Corp.

Cat-Floc
Cat-Floc B
Coagulant Aid 233
Coagulant Aid 235
Coagulant Aid 243
Coagulant Aid 253

Dow Chemical Co.

Purifloc A23 (Potable Water Grade)
Purifloc C31
Purifloc C41
Purifloc N17
Purifloc N20

Gamlen Chemical Co.

Gamlose W

Hercules Inc.

Hercofloc 812.3
Hercofloc 815.3
Hercofloc 818.2
Hercofloc 821.2
Hercofloc 827.3
Hercofloc 831.2
Hercofloc 834.1

ICI America (Atlas Chemical Co.)

ATLASEP 2A2
ATLASEP 3A3
ATLASEP 4A4
ATLASEP 105C

Nalco Chemical Co.

Nalcolyte N-607

Narvon Mining & Chemical Co.

Zeta Floc C
Zeta Floc O
Zeta Floc WA

Philadelphia Quartz Co.

Polymer XP-233C
Polymer XP-800N
Polymer XP-950A

SECTION VII

LITERATURE ABSTRACTS

The AWWA Research Foundation, as a central information resource, collects, abstracts, and indexes all available literature on the treatment and disposal of wastes from water treatment plants. The abstracts conform with the specifications of the Water Resources Science Information Center (WRSIC), which reviews, edits, and stores the abstracts in a computerized system for ready retrieval. The abstracts are published by the Office of Water Resource Research, U.S. Dept. of the Interior, in Selected Water Resources Abstracts.

The Research Foundation has assembled and reviewed technical articles from a variety of sources. These sources include: papers delivered at national and local AWWA section meetings; articles identified through literature searches; and articles transmitted to the staff by members of the advisory committee, and practitioners in the engineering, plant operation, and research fields.

The 121 abstracts which appear on the following pages present capsule summaries of technical articles on water plant waste treatment. For convenience, the abstracts are grouped by their original title under broad general headings. In many cases, a paper may provide valuable information encompassing a wide area of inquiry and endeavor. For this reason, examination should be extended to other headings to note such possibilities. The classification title of "Waste Problems at Specific Water Treatment Plants" might prove rewarding in this respect.

The 121 abstracts prepared during the course of this project phase, coupled with the 72 published in the 1971 Report brings the total collection to 193. The original papers are on file at the American Water Works Association Research Foundation for inspection or can be copied and mailed at the cost of handling.

The abstracts are arranged under the following classifications.

TABLE 3
CLASSIFICATION OF LITERATURE ABSTRACTS

<u>Classification</u>	<u>Page</u>
Waste Problems in Specific Water Treatment Plants	18
Waste Treatment in New Water Treatment Plants	28
Water Conditioning Practices	29
Water Treatment Plant Wastes	
Review Articles	31
Committee Reports	33
Characteristics of Wastes	34
Treatment of Filter Washwater	35
Treatment of Sludges	
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WASTE PROBLEMS IN SPECIFIC WATER TREATMENT PLANTS

Almquist, F.O.A., "Problems in Disposal of Sludge and Washwater for Connecticut Water Filtration Plants", Journal NEWWA, Vol. 60, No. 4, pp. 344-358, December 1946.

Key Words: Lagoons, Waste dilution, Filter washwater, Basin sludge, Drying beds

Review of data from sludge analysis at purification facilities discussing plant problems and possible remedies. Physical and chemical sludge data are tabulated and bacteriological tests reported. Six treatment plants using alum coagulants found different sludge handling solutions. Three plants lagooned this waste and decanted the supernatant. Sludge drying beds with 4" underdrains topped by graded gravel and sand dewatered filter washwater and basin sludge at one utility. One plant discharged to a meadow while another plant transported by pipe to a larger receiving stream for dilution. Eleven plants diluted their waste. A table of practice in cleaning basins showed cleanings per year, disposal methods, complaints, and remarks for 17 plants. Author suggests additional remedies and need for further research.

Ash, R.V. "The Great Eau Scheme: North-East Lincolnshire Water Board", Journal of the Institution of Water Engineers, Vol. 20, No. 7, pp. 435-458, October 1966.

Key Words: Water purification, Water softening, Sludge treatment, Design details

Study reports initial investigation and design details for the intake works, treatment processes, and aqueduct for a water supply system. The cost of the scheme was estimated at 4.3 million pounds. Quality data are presented for color, hardness, chlorine, and iron and manganese content of the raw water. Proposed treatment included: cascade aeration; precipitators with mechanical flocculators and upward flow for partial or split softening and clarification; rapid gravity filters; stabilization; and disinfection with breakpoint chlorination. Details are provided on the clear water reservoir, chemical storage and dosing system, and washwater recovery and sludge disposal. The 40,000 gallon tanks, equipped with agitators, store washwater. The sludge from these tanks is sent to the precipitators. Precipitation sludge is concentrated in slow stirring thickeners with supernatant water returned to the precipitation inlet. Sludge is pumped to sea.

Carter, R.C., Ludwig, H.F., Ongerth, H.J., Harmon, S.A. & Woody, S.H., "Behavior and Evaluation of Microstraining for a Supply in California", Journal AWWA, Vol. 54, No. 5, pp. 606-620, May 1962.

Key Words: Filtration, Microstrainer

Description of the installation of a microstrainer and details of a method to evaluate its performance. The water source increased in turbidity and coliform organisms. A 10-foot diameter by 10-foot microstrainer was installed and provisions made for 3 more. Automated operation parameters included: 30-100 fpm drum speeds; 35-100 gpm backwash flow rates at pressures of 15-25 psi; and use of ultra-violet light to reduce bacterial slime on the stainer fabric. Particulates were classified in size groups according to type and composition. A relationship was developed to calculate the size of the average volume particulate. An average particulate volume index of 25 μ or larger means excellent removal. The report concluded: the removal efficiency of particulates improves with increased total volume or large average particulate volume debris particles, comprising an agglomerated mixture of materials, diatoms and organic debris, tend to disperse during microstraining; and straining reduces chlorine demand appreciably and may effect some coliform removal.

Cartwright, F., "Design of Farmoor Treatment Works, Oxford Corporation Water Department", Journal of the Institution of Water Engineers, Vol. 18, No. 5, pp. 381-412, August 1964.

Key Words: Water purification, Sludge treatment, Design considerations

This study reviewed the problems and design considerations for the four stage development of a 24 mgd water purification plant. A reservoir is planned to furnish an adequate raw water supply. Advantages and disadvantages of the treatment site are discussed. The source water is stable and non-corrosive, but prone to periodic taste and odor problems. Physical and chemical water characteristics are tabulated. The plant layout included: aerator, micro-strainers; settling tanks; filters; pump and control housing; treated water storage reservoir; chemical house; administration building; electrical substation; diesel house; garage and cycle shed; dirty washwater and sludge settling tanks; sludge settling lagoons; automatic controls; alarm system; and oil-fired burner. Some contract cost and design specification data are provided. These data described the facilities enumerated under the plant layout. Thickened sludge is settled in a lagoon. Decanted supernatant is discharged to a nearby brook. Duplicate filter washwater tanks and sludge thickening tanks are provided.

Collins, P.G.M. & Gibb, O., "Design and Construction of the Fixby Water Treatment Works for Wakefield and District Water Board", Journal of the Institution of Water Engineers, Vol. 18, No. 6, pp. 491-502, October 1964.

Key Words: Sludge treatment, Water purification, Site selection, Construction details

The article reviewed site selection criteria, proposed treatment methods plant operation and construction details, and washwater and sludge treatment processes for a 7 mgd water treatment plant. The treatment facilities included: ferrous sulfate coagulation; pH conditioning; hydraulic mixing; mechanical flocculation; upflow sedimentation; breakpoint chlorination; rapid gravity filtration; automatic residual chlorine control; filtered water storage; and waste handling facilities. Filtration flow rates are 101-121 gallons/sq ft/hr through a graded quartz sand bed on graded gravel with a perforated asbestos cement pipe underdrainage system. Filter washwater is settled in duplicate recovery tanks of 60,000 gallons capacity. Supernatant is recycled to the plant inlet. Concentrated sludge is periodically withdrawn and pumped to lagoons for drying and ultimate disposal. Sludge lagoons are an interim treatment measure. Chemical handling facilities are described. Building and general layout, and structural design details of the clear-water reservoir, precipitators, filters, and ancillaries are presented. Concrete mix and design data are listed. Appendices included contractors and design and administration information.

Dittoe, W.H., "Disposal of Sludge at Water Purification and Softening Works of the Mahoning Valley Sanitary District", Journal AWWA, Vol. 25, No. 11, pp. 1523-1530, November 1933.

Key Words: Water purification, Water softening, Holding ponds

This study explained the elements entering into the design and operation of sludge holding ponds. The 40 mgd treatment facility employs purification and lime-soda ash softening with filtration. Lime, soda-ash, and alum are mixed with raw water. The precipitates settle and the process water is carbonated. There is sludge recirculation prior to filtration and continuous sludge removal. Sedimentation tank sludge is settled in two ponds, each holding one year's sludge production. Waste supernatant will overflow to the river, evaporate, and seep into the ground. Tabulations are presented for sludge produced in treatment and the volume and percentage of water in one ton of sludge. Sludge is pumped 1300 feet in 4 inch line to the ponds. Decantation equipment is provided in each pond. A pond supernatant less than 15 ppm turbidity is disposed in a creek. Solids removed may be used in soil treatment. The ultimate success of disposal depends on how effectively sludge utilization can be promoted.

Doe, P.W., "The Design of Washwater and Alum Sludge Disposal Facilities for Passaic Valley Water Commission", Paper presented at Annual AWWA Conference June 6, 1972, Chicago, Illinois.

Key Words: Filtration, Filter press

In 1967, the Passaic Valley Water Commission initiated a program to review all aspects of water treatment plant sludge disposal. Filter pressing appeared most promising. A Beloit-Passavant press was used for pilot plant studies. Preliminary data was developed to establish waste sludge quantity of filter washwater and sedimentation basin material. A backwash settling tank was designed to: settle the suspended solids and return the supernatant overflow to the plant inlet; or collect backwash water, mix it, and return the mixture to the plant inlet to provide sites for coagulation. Polymer is added. The sludge thickening complex will treat sedimentation basin sludge and underflow from the backwash settling tanks. Sludge is stored, centrifuged, and conditioned with lime before filter pressing. The filter cloths are precoated to produce an easily stripped cake. Each press has a 220 cubic foot capacity. EPA has not approved construction funding for this flexibly designed facility.

Earnshaw, F., "Design of the Yorkshire Derwent Headworks", Journal of the Institution of Water Engineers, Vol. 16, No. 2, pp. 139-159, March 1962.

Key Words: Water Softening, Sludge treatment, Specifications

This study outlined treatment plants for a 25 mgd water softening facility. The intake site for the tidal source was chosen for: minimal interference to the freshwater regime; ability to provide water and avoid heavy silting; and a foundation suitable for construction of a pump house and treatment works. Flow occurrence probability records and formulae are presented. Treatment included: lime (lime-soda) softening in upward-flow reaction tanks with clarification aided by a coagulant useful at high pH values; stabilization and chlorination in a baffled contact tank; rapid gravity filtration; dechlorination and ammoniation; treated water storage. The nature of the site, layout of the works, and preemptory specifications for the intake and low-lift pumps are provided. Details are discussed for the reaction tanks, flash mixer and contact tank, filters, and automatic controls. The controls will monitor: raw and treated water flow, river levels, intake system condition, chemical handling and storage facilities, and filter washing. Consideration is being given to sludge dewatering by centrifugation. It is thought the sludge has agricultural value. Permanent sludge dump sites include unused gravel pits and quarries, and abandoned canal, and an estuary. Sludge will be lagooned on site for the first 12 months of operation while handling methods are evaluated.

Evans, G.R., "Discussion On Use of Microstrainer Unit at Denver", Journal AWWA, Vol. 51, No. 3, pp. 358-362, March 1959.

Key Words: Filtration, Microstrainer

This discussion provided data on the microstrainer construction, washing process, operating results, and applications. Strainer flow rates of 30 gpm/ft² have been reached. Flow depends on the mesh fabric apertures and raw water suspended solids concentration. Filterability index, flow volume, rotational drum speed, fabric area, and head loss are interrelated variables that must be considered in design. Water pressure for washing is a function of the incoming raw water quality, drum speed and fabric mesh. Average wash water pressure was 18-20 psi with 35 psi a maximum. Wash water averaged 1.7% of through flow. Occasional cleaning of the mesh with a 12-15% sodium hypochlorite solution was required in the summer when *Asterionella* predominated. Operating results for this and other plants are discussed. Nearly 100 installations were cited in construction or operation. Microstraining has become a sole filtration process in both public and industrial supplies. This process can serve as a primary treatment ahead of rapid sand filters in a manner similar to installation in front of slow sand filters.

Forster, Hans, "Test Results on Basin Sediment From the Chattahoochee Water Treatment Plant, City of Atlanta, Ga.", Private Communications, January 1970.

Key Words: Filter pressing, Alum sludge

The City of Atlanta purchased Beloit-Passavant Sludge Dewatering Equipment to dewater the alum sludge generated at the Chattahoochee Water Treatment Plant. The purchase of this equipment followed extensive testing in which air flotation, vacuum filtration, centrifugation, and filter pressing processes were carefully evaluated. This will make Atlanta the first United States city to dewater alum sludge by filter pressing on a plant scale basis. Seven new filters are under construction that will increase the plant design capacity to 60 mgd. The full scale plant will consist of two series 6400 Beloit-Passavant Pressure Filters. The presses are expected to produce a filter cake with a solids concentration between 40 and 45%. The alum sludge will be conditioned with lime before processing. The filter cake can be disposed of as a landfill. The capacity of the two filters being installed is approximately 55,000 pounds of dry solids daily. It is expected that the Chattahoochee Sludge Dewatering Plant will go into service late 1971. For additional information, contact Mr. Hans W. Forster, Product Manager, Beloit-Passavant Corporation, Carson Road & Hwy 79 N.W., P.O. Box 2503, Birmingham, Ala. 35202.

Fujita, H., "Tokoyo's Asaka Purification Plant", Water & Sewage Works, Vol. 14, No. 3, pp. 73-82, March 1967.

Key Words: Water purification, Alum recovery, Washwater recovery

This study outlines design and construction data for a \$73.5 million purification plant treating a raw water with normal turbidity 10-50 ppm, COD 1 ppm, and manganese 0.1-0.3 ppm. Features include: space-saving layout and structure; unique sedimentation basins; deep-well underground buildings; huge pump installations; and supervisory control system. Details are provided on the raw water intake and conveying facility; receiving well and sedimentation basins; rapid sand filters; administration house and clear water pumping station; clear water reservoirs; chemical plant; power supply installation; and washwater and sedimentation basin sludge disposal system. Washwater is settled in 1.2 million gallon basin and returned to the receiving well by wash-waste pumps to recover 26-53 mgd of water. Sedimentation of sludge is concentrated and dewatered in the plant. Sulfuric acid is added to the sludge. Alum is recovered for reuse. Thickened inert material is vacuum filtered with the cake used for landfill.

Gordon, F.G., "Economics of Sludge Removal from Rectangular Basins at Chicago", Journal AWWA, Vol. 48, No. 9, pp. 1125-1132, September 1956.

Key Words: Economics, Manual cleaning, Mechanical sludge removal

This study compared the economy and efficiency of manual and mechanical sludge removal methods on plant operation. The basins were double-decked rectangular parallel-flow units. Detention times and flow velocities are tabulated for the 320 mgd facility. The utility of scrapers in the entire settling basin could reduce the shutdown time for cleaning, necessary inspections and maintenance by 60 days. Data are presented for complete mechanical sludge removal and the relationship of microorganisms and turbidity in settled water to average filter run lengths. The installation and operation of mechanical sludge removal equipment in one third of the basin reduced the amount of drained sediment requiring manual cleaning. Complete sludge removal equipment could decrease shutdown time from 20 to 4% per year. Complete removal equipment was unjustified because the net annual increase in operating expenses and fixed charges was \$ 72,420. The plant operation was not impaired by sludge accumulation in the settling basins. Filter run length was dependent on the number of microorganisms in the settled sludge.

Griffiths, J.H.T., & Wiedish, W.J.L., "Diddington Treatment Works: Great Ouse Water Supply Scheme", Journal of the Institution of Water Engineers, Vol. 21, No. 2, pp. 103-126, March 1967.

Key Words: Water softening, Water purification, Sludge treatment, Design considerations

Design and construction aspects of a water softening clarification facility are reviewed. The site had good access, nearby delivery mains, and sufficient area. Quality goals included: softened water with a constant total hardness ratio; and acceptable chloride/carbonate hardness ratio. Physical and chemical source water quality data are tabulated. Flexible treatment processes were: cascade aeration; flash mixing; reaction tanks for softening and clarification; rapid gravity filtration with air scour, low velocity wash, and surface flush provisions; sludge concentration; and storage handling facilities for ferrous sulfate, alumina, lime, soda ash, sodium silicate and sulfuric acid. Preliminary chemical house considerations included: positioning relative to reaction tanks, bunker height and weatherproofing, and lorry bay size. A Candy centrifugal-balancer-proportional-speed chemical system was utilized. Provisions for pH correction, activated carbon, and controls and signalling are discussed. Separate lagoons process washwater-clarification sludge and softening waste. Architectural and landscaping details are provided with information on the initial running of the plant.

Heney, P.D. "REPORT ON WASTES FROM MISSOURI AND MISSISSIPPI RIVER WATER TREATMENT PLANTS FOR MISSOURI RIVER PUBLIC WATER SUPPLIES ASSOCIATION", Report for Missouri River Public Water Supplies Association, Project Number 6044, December 5, 1972.

Key Words: Sludge disposal, Water purification, Water treatment, Sludge

Data are presented on the sources, quantities, and characteristics of wastes emanating from 16 water treatment plants located at Omaha, Neb; Council Bluffs, Iowa; St. Joseph, Atchison, Leavenworth, Kansas; Kansas City, Lexington, Boonville, Jefferson City, and St. Louis City and County, Missouri. All plants embody multi-stage mixing, sedimentation basins, and rapid-sand filters plus coagulation with alum or iron salts, disinfection with chlorine, and in the majority of plants, lime softening. Raw water pumpage is less than 1 percent of river flow. River sediment removed from and then returned to the river is an extremely small part of the total sediment load carried by the river. Basin cleaning results in "slug" discharges which produce minimal adverse effects on quality. Chemical solids from the 12 softening plants are composed principally of calcium carbonate, minor amounts of the hydroxides of magnesium, iron and aluminum, trace amounts of manganese derived from lime, river sediment, or potassium permanganate applied for odor reduction. Prechlorination has a negligible effect on the production of chloride returned to the river. The pH of treatment plant wastewater is in the 6.5-10.5 range and produces no detectable effect after discharge into the river. The overall chemical solids on river water quality are virtually nil. Downstream water treatment plants would not be benefited by the elimination of discharges from upstream water treatment plants because such discharges are undetectable.

Lathrop, T.R., "Discussion of Disposal of Sludge at Water Purification and Softening Works of the Mahoning Valley Sanitary District", Journal AWWA, Vol. 25, No. 11, pp. 1530-1533, November 1933.

Key Words: Ultimate disposal, Continuous sludge removal

A serious problem of handling softening sludge developed with continuous sludge removal, low river flows, and complaints due to creek discoloration. Softening sludge at Oberlin, Ohio, had a specific gravity of 1.13-1.17, 72-85% water content, and density of 70.5-73 pounds/ft³. The Columbus, Ohio plant received complaints after waste discharges were noticed in the Scioto River. Sludge discharge at Newark, Ohio, created sludge blankets in the river. Sludge was pumped to an abandoned quarry and borrow pit in Marion, Ohio. An experimental vacuum filter reduced moisture content to 50%. The sludge has value equal to agricultural lime for soil neutralization. In Fostoria, Ohio, sludge is settled in tanks and discharged to low ground. In Miami, Florida, a 1 to 2 inch covering was excellent for growing grass and vegetables on account of its quality of holding moisture. The Sandusky, Ohio facility settles and decants their waste. The major problem is ultimate disposal of solid wastes.

Levis, C.E., and Smith, W.B., "Lancaster's New Water-Treatment Plant", Journal AWWA, Vol. 64, No. 1, pp. 25-28, January 1972.

Key Words: Water treatment, River intake

Design and construction considerations are enumerated for a new water treatment plant with sludge handling facilities. A supplementary water source required further development. The existing plant treated 8 mgd and included: 2 clarifiers; 4 rapid sand filters; a 0.3 mgd backwash tank; 2 mgd clearwell; 3 high service pumps; and chemical feed equipment. A new river intake structure was designed to resist ice floe forces, self-scour at the entrance to minimize sedimentation from the river-bed load, have a manually cleaned. The pump selection data and clarifier specifications, including glass-fiber reinforced plastic internals for the high rate solids contact units, are given. An electronic automation system is used. Filter backwash water is settled in a holding tank with the supernatant pumped to the raw water line. Sludge from the clarifiers is concentrated in a gravity-type thickener. Sand beds were designed on the basis of laboratory studies to dewater the sludge.

Lynch, W.O. Baker, C.R., and Haberer, J.H., "Experiences with Microstraining at Ilion", Journal AWWA, Vol. 57, No. 11, pp. 1422-1430, November 1965.

Key Words: Algae, Microstrainer

The installation of a microstrainer before slow sand filters eliminated filter clogging due to excessive algal growths in raw water during summer months. Copper sulfate was ineffective in controlling algae in one impounded surface source. A 7.5 foot microstrainer was installed with diatomaceous earth filters to pretreat raw water at Ilion. The effects of microstraining were beneficial in sustaining the output of slow sand filters and lengthening filter runs by removing microorganisms. Penetration of material into the sand beds increased with microstrainer pretreatment. It appeared the Schmutzdecke thickness was increased due to the removal of active zoogeal mass in a strainer. The mass forms a rough mat that removes fine particles before entering the bed. More frequent resanding would be required. A filter was evaluated using an artificial diatomaceous earth Schmutzdecke. The diatomaceous earth coating stopped deep sand penetration of matter without influencing filter efficiency. The required filter area was reduced 28% and the net cost of skimming the filters dropped by \$2600/year.

McCaughan, F.A.; "Preliminary Engineering Report, Proposed Waste Water Treatment Facilities For Nueces County Water Control & Improvement District No. 3". Private Communication, October 1970.

Key Words: Alum and lime sludge, Filter washwater, Settling basins, Ultimate disposal

Reagan & McCaughan, Consultant Engineers from Corpus Christi, Texas, have proposed waste treatment facilities to control the pollution caused by sedimentation tank sludge and filter backwash water at a Nueces County Water Control & Improvement District No. 3 water treatment plant. This utility provides 1.5 MGD of domestic water for the City of Robstown and the surrounding area. Lime, alum, and chlorine are used to treat the raw water at this plant. The source water is pumped from the Nueces River into an earthen canal and then flows into a series of lakes at the treatment plant site. The wastewater from the coagulation and filter washing processes is presently discharged to a drainage ditch owned and operated by a Drainage District. The Texas Water Quality Board has noted objections to this procedure and has advised the District to find a new disposal technique. The consultants have proposed that the sludge and filter washwater be treated in earth settling basins. The clarified effluent could then be returned to the raw water lake. Two basins were provided to allow operation of one and cleaning of the other. The sludge from these basins would be ultimately disposed of at a suitable site. The settled sludge may have utility as a fertilizer for grain or cotton crops.

Milne, J.W., "The Pitsford Treatment Works of the Mid-Water Engineers", Journal of the Institution of Water Engineers, Vol. 12, No. 1, pp. 83-105, February 1958.

Key Words: Design data, Water softening, Filter washwater, Basin sludge

This paper discussed the treatment facilities for water softening an impounded water supply and the pumping considerations. The treatment site was chosen for uniformity in slope, optimization of pumping operation, and placement from sludge treatment units. Design and construction details are provided for: general arrangement of plant and buildings; raw water pump house; chemical block; reaction tanks; filters with automatic controllers; filtered watertank; main pump house and auxiliary engine house; chemical handling; chemical mixing and feeding; sterilization and stabilization; output control; and washwater and sludge disposal. Two 93,500 gallon settling tanks are provided for filter washwater. Lime-soda softening sludge from the concentrator and washwater settling tanks are pumped to a centrifuge. The centrifuge can handle a 10% sludge at 2500 gallons/hour and produce a 40-50% cake by weight for landfill. An emergency sludge bed is provided in case of electrical failure to the centrifuge, conveyor, or shear pin of centrifuge gear unit. Information is provided on electricity supply and instruments, structural and building details, and operating experience. Appendices are shown for: composition of main control and instrument panel; motors required in plant operation; and main contracts awarded.

Plautz, W.H. & Van Kirk, F.N., "Comprehensive Report on Disposition of Sediment and Waste Backwash Water at the Central and South Water Filtration Plants, City of Chicago, Illinois", Consoer, Townsend & Associates, Consulting Engineers, 360 E. Grand Ave., Chicago, Ill. 60611, 78 pp., February 4, 1970.

Key Words: Quantities and Flows, Disposal of Wastes, Cost and Maintenance

This report presents analyses of quantities and flows of both sediment and waste backwash water at both Central and South Water Filtration Plants. Various possible alternate solutions for disposition of the wastes are discussed and analyzed including capital expenditures, operating costs and maintenance costs. Recommendations based on economic feasibility and good engineering practices are presented.

Sankey, K.A., "The Problem of Sludge Disposal at the Arnfield Treatment Plant (Manchester Corporation Waterworks)", Journal of the Institution of Water Engineers, Vol. 21, No. 4, pp. 367-378, 1967.

Key Words: Dewatering, Filter pressing, Sludge conditioning

Several sludge dewatering processes are systematically evaluated at the Arnfield Treatment Plant. Conclusions on optimum sludge concentration and hydraulic capacity, bed covering, draining and drying cycle, layering effects, mechanical cleaning, and design criteria are presented for wedge wire sludge filtration. Experimentation with a diatomaceous earth precoat of a rotary-vacuum filter on a lime conditioned sludge was promising. Preliminary determinations for filter pressing included the degree of preconditioning, effluent quality, cycle time, and cake disposal problems for this process. Conditioned sludges were more easily dewatered than untreated sludges. Hydrated lime was a good conditioner. Slow-stirring thickening did not enhance dewatering characteristics significantly. Capital and running costs are tabulated for wedge-wire and rotary-vacuum filtration, filter pressing, and freezing operations. Filter pressing appeared most economical. A discussion of system parameters including cake discharge, automation, downtime, and cloth life is presented for the filter press. The final design incorporated lime conditioning, provision for slow-stirring thickeners, and a semi-automatic press. The press supernatant will be recovered.

Shimmer, J.S. & Davison, A.S., "The Development of Bough Beech As a Source of Supply (The East Surrey Water Company)", Journal of the Institution of Water Engineers, Vol. 25, No. 5, pp. 243-260, July 1971.

Key Words: Water softening, Water purification, Power generation, Distribution pumping

This article reviewed the development of a surface supply capable of yielding 5-6 mgd with a maximum of 10 mgd. Reservoir and intake site selection was based on water quantity available; an abstraction formula; water quality; and storage effects. The design philosophy considered: average/maximum yield relationships; river works; conjunctive use of underground chalk water and greensand supplies, and surface storage; plant flexibility; distribution needs; phasing of development; power supply; and controls and instrumentation. The softening-clarification facility and pumping station was to provide water treatment, power generation, and pumping to supply. Treatment includes: reaction tanks equipped for softening, clarification, and recirculation; rapid gravity sand filtration; carbon pressure filtration; treated water reservoir; pH correction units; chlorination and ~~ammoniation~~ equipment. The generating plant is to provide flexible operation with 3.3kV at the river works and 250kVA at the mains. Softening and clarification wastes are separately handled. Sludge is concentrated with supernatant water returned to the settled water channel. Experiment bays are used to study methods to dispose concentrated sludge and filter washwater. Appendices summarized physical-chemical water quality data for the river and reservoir; principal technical data and consultants; and approximate costs.

Skinner, W.D., "Winfield Wins a New Water Supply", Willing Water, Vol. 16, No. 3, pp. 8-9, March 1972.

Key Words: Water purification, Lagoons, Surface impoundment, Washwater reclamation

The report outlined a \$3.6 million water improvement program including: surface water impoundment, water treatment plant, raw and finished water transmission mains, and elevated storage tanks. Winfield utilized well supplies until improper brine disposal methods from oil wells caused salt-water intrusion into the aquifers. The development of an impounded alternative provided the best quality raw water for supply and recreation. City, Department of Housing and Urban Development, and Soil Conservation Service costs are tabulated. Raw water flows by gravity from the reservoir to a conventional clarification plant with solid contact basins and dual media filters. Pre-sedimentation basins, secondary mixing basins, clearwell, treated water storage reservoir, washwater reclamation basin, and two sludge lagoons are included. Flexible treatment operation is planned to cope with taste and odor problems. Filter washwater is reclaimed in 72,000 gallon basin. Basin sludge is lagooned or settled in ponds. New distribution lines are tied to existing water mains.

Smith, F.E., "A Study of Sludge Disposal at Water Purification Plants in New England", Journal NEWWA, Vol. 62, No. 4, pp. 265-274, December 1948.

Key Words: Sludge treatment, Sludge production, Sludge accumulation

This paper discussed sludge production and disposal procedures for iron salt, mud, coarse suspended solids, color, bacteria, and microscopic organisms. Sludge production and accumulation is influenced by raw water character, coagulation efficiency, and basin performance. General basin cleaning procedure is to dewater the tank and pump out the sludge. Mechanical and daily sludge removal procedures allow continuous operation; eliminate duplicate units and reduce number and size of basins; increase efficiency; lower operation, maintenance and initial costs; prevent sludge decomposition in basins; and are more flexible for design and operation. Sludge disposal methods included release with domestic sewage, discharge to rivers, stream reservoirs, lakes, or ponds, and lagoons. In discharge to watercourses, dilution, sludge blanketing, and silting must be considered. Waste transported to a sewage treatment plant must be examined in relation to sewer system damage, amenability to existing treatment process, hydraulic and biological plant interferences, and effect on final plant effluent. Final solids removal is suggested by recovering humic acids and humates or by landfill. The best method appeared to be mixing with domestic sewage.

Turre, G.J., "Use of Microstrainer Unit at Denver", Journal AWWA, Vol. 51, No. 3, pp. 354-357, March 1959.

Key Words: Filtration, Microstraining

The study described the construction and operation of a microstraining process to remove microorganisms at a Denver water purification plant. Dimensions of the strainer and steel tank are given. The drum is three-fifths submerged with a rotational capacity of 0.5-4.0 rpm. The unit, rated at 2.0 mgd, had processed 3.9 mgd of water with 3.0 ppm turbidity. Construction details and materials are provided. Raw water enters the drum axially and flows radially through the fabric. Head loss is less than 5-6 inches. A washwater hopper collects material from drum washing, then drains into the hollow axle of the drum following through the center of the bearing located on the upstream side of the unit. A row of cleaning jets on the outside top of the drum flushes solids into the washwater trough. The jet slots are self cleaning. Wash water requirements are low. Laboratory tests are made on the type and percentage of organisms removed and turbidity reduction. Percent wash water used, water strained, washing pressure, and head loss are recorded at the site. A comparison is made of microstraining and filtration.

Webster, J.A., "Operational and Experimental Experience at Daer Water Treatment Works With Special Reference to the Use of Activated Silica and the Recovery of Alum from Sludge", Journal of the Institution of Water Engineers, Vol. 20, No. 3, pp. 167-198, 1966.

Key Words: Sludge treatment, Sludge disposal, Alum recovery

This study describes design and operating criteria developed at the Daer Waterworks to enhance purification sludge settleability and reduce sludge volume for disposal. Activated silica is utilized as an aid to aluminum sulfate. An automatic de-sludging system including a retention mixing tank, chemical handling and dosing facilities, and additional sedimentation tanks is described. The sludge volume was assessed through laboratory and plant testing. Filter pressing of this sludge was not economical. Experimentation focused on slow-stirring thickening, alum recovery, and freezing of the settled sludge. The recovered alum produced a good floc in the raw water during laboratory tests. A pilot plant was constructed to develop design parameters for the thickening, alum recovery, and freezing operation. Design criteria and operating data are presented for the pilot plant. Refrigeration power costs and chemical savings costs are tabulated. A small sludge cake must be disposed of from the freezing process.

Weir, P., "Atlanta's Water Treatment Settled Solids Facility", Paper Presented at the 92nd Annual Conference of the American Water Works Association, June 6, 1972, Chicago, Illinois.

Key Words: Recycling, Pressure filtration, Settled solids

Settled solids from the Hemphill water treatment plant were discharged to a combined sewer system. Filter washwater was transported to the Atlantic Steel Company for use as cooling water. Settled solids from the Chattahoochee plant were discharged to the river. The alum coagulation sludge could be tolerated at the sewage plant if processes were enlarged and maintenance problems due to the abrasive nature of the solids were overcome. Sludge was first recycled to the intake reservoir at the Hemphill plant, but manganese built-up in this water. The system installed at the Chattahoochee plant included: sludge holding and mixing tanks; pressure filters; chemical system; feed facilities; and space for loading sludge cake. The 110 ft³, 44-chamber filters operate at 225 psig with 1813 ft² of area. A 90 minute cycle with 100# diatomaceous precoat and 7-10% lime can produce a 40-50% solids cake and a 10 ppm suspended solids filtrate. Filter washwater is settled, with supernatant recycled. The facility cost \$2.8 million. A pilot filter is described. Similar equipment planned for Hemphill will cost \$10.6 million. Benefits include: recycling washwater and filtrate; easy handling of dewatered solids; and minimum land requirement.

Wilcock, E.J., and Sard, B.A., "Design and Operation of the Carmoney Water Treatment Works: Faughan River Scheme - Londonderry R.D.C.", Journal of the Institution of Water Engineers, Vol. 18, No. 6, pp. 477-490, October 1964

Key Words: Water purification, Sludge treatment, Washwater

This study provided preliminary treatment design criteria for a water purification plant. The ultimate plant capacity of 15 mgd in 3 stages was to supply industrial and domestic consumers. Tabulated raw water quality showed seasonal variations and rapid changes. A flexible treatment scheme is needed. Proposed treatment included: alum coagulation; pH control using sulfuric acid; provision for a "weighter"; mechanical flocculation; sedimentation; rapid gravity filtration; pH conditioning for distribution; and sterilization. The intake works contain screening and chlorination equipment. Horizontal flow sedimentation basins with mechanical agitation equipment were chosen. These units are the least sensitive to changes in water quality and flow rates. Chemical handling facilities are described. Filtration flow rates are 73-87gph/sq.ft. through graded Leighton Buzzard sand and graded pebbles with a non-ferrous pipe underdrainage system. Filter washing procedures included air scour, upward water wash, and horizontal surface flush. Two washwater holding tanks, each of 50,000 gallon capacity, equipped with slow moving paddles to prevent sedimentation, settled filter washwater. Supernatant washwater is returned to the plant inlet. Sludge from the washwater holding tanks and sedimentation basins is sent to lagoons. Operational experience, remedial measures, and plant cost details are provided.

Young, E.F., "Water Treatment Plant Sludge Disposal Practices in the United Kingdom", Journal AWWA, Vol. 60, No. 6, pp. 717-732, June 1968.

Key Words: Sludge treatment

This review reported on specific sludge treatment technological applications at English Water utilities. Physical and chemical character of coagulation and softening waste was discussed. Two important initial parameters are sludge volume and concentration. A figure showed successive alternative stages in sludge disposal. Drainage time for hydroxide sludge was related to the square of the applied sludge depth. The Water Research Association claimed: softening sludge dewatering characteristics can be controlled by the method used; shallow covered lagoons are needed for hydroxide sludge; and polymers with molecular weights of 1,000,000 or more added to settled sludge are effective. The Stocks and Fishmoor plants use slow stirring thickeners and a freezing tank. The Broughton Softening Works used a pellet seed reactor. The Manchester Corporation Arnfield plant holds, thickens, and filter presses basin sludge; and microstrains and rapid gravity filters backwash water. Both supernatants return to the plant inlet. The Daer Water Board has sedimentation tank sludge and settled washwater sludge that is acidified and thickened to reclaim alum. Remaining sludge is frozen. Other facilities listed thicken, lagoon, and centrifuge wastes. Design should be flexible and follow laboratory or pilot testing.

WASTE TREATMENT IN NEW WATER TREATMENT PLANTS

Cedroni, E., "Considerations in Large Water Plant Design", Journal AWWA, Vol. 64, No. 5, pp. 299-303, May 1972.

Key Words: Water treatment, Central control panel, Drying beds

Design criteria are given for a water treatment plant utilizing a functional central control panel and providing waste disposal. Construction details are given for the submerged timber intake crib. Initial problems and solutions in constructing the intake shaft and surveying the raw-water tunnel are described. Details are provided for the low-lift plant, high-lift plant, chemical handling and storage facilities, settling tanks, and filtration plant. Sanitary wastes are disposed in septic tanks. Filter washwater is recirculated. Sludge from the settling basins is clarified with the supernatant overflow recirculated. The condensed sludge is discharged to drying beds. A central control panel is explained. The only information on the board is that needed by the operator to make decisions within the plant.

DeFillippi, J.A., "Designing Filtration Plant Waste-Disposal Systems", Journal AWWA, Vol. 64, No. 3, pp. 185-187, March 1972.

Key Words: Sludge treatment, Basic data collections, Design process, Subsystems

Regulatory agencies will not accept shock or concentrated loads to water-courses. Increasing land costs in urban areas make lagooning expensive. Recycle systems may be economical. This study showed long-term lagooning as treatment for backwash and clarifier wastes can be eliminated. New design requires: definition of sludge dewatering characteristics; choice of design processes, subsystems, and final layout. Suspended solids concentrations of waste volumes are of interest. Correlations of turbidity and suspended solids and sampling - laboratory programs are suggested. The plant process, operation, raw-water flow-quality data, and physical layout must be considered before programs are detailed. Treatment alternatives include coagulation-settling of backwash and clarifier sludge thickened; or mechanical dewatering of clarifier sludge separately with special surge tank for washwater. Mechanical dewatering processes for alum-lime sludge are centrifugation; vacuum filtration, and pressure filtration. Following laboratory tests on thickened-unthickened sludge with and without chemical pretreatment, pilot-scale tests should be initiated. Basic data must be available for design development.

John, Robert L., "Filter Plant Includes Waste Treatment", Water & Sewage Wastes, Vol. 118, No. 4, pp. 96-98, April 1971.

Key Words: Waste treatment, Thickening, Alum sludge

This paper describes the instrumentation, chemical handling, equipment, and plant facilities of a water filtration plant designed to treat its filter wash water and settling basin sludge. The Clean Streams Law of Pennsylvania requires treatment of purification plant wastes. The filter wash water facilities include a wash water sump and pumps to return the wash water to the raw water supply entering the plant. The wash water provides artificial turbidity which is believed to enhance coagulation and flocculation. Provisions are available to partially dewater this waste in a clarifier-thickener. The alum sludge from the settling basins is discharged to a sump before entering the thickener. Supernatant from the thickener contains less than 100 mg/l suspended solids and is discharged to a stream. A 4 to 5 percent solids sludge is pumped from the thickener to a sump. The alum sludge is pumped into tank trucks for hauling to a pit-lagoon offsite disposal area. Various industrial wastes are disposed there. A tabulation is made of the equipment suppliers, and construction costs for the water treatment facility.

Proudfit, D.P., "Selection of Disposal Methods for Water Treatment Plant Wastes", Journal AWWA, Vol. 60, No. 6, pp. 674-680, June 1968.

Key Words: Recalcining, Chemical recovery

A study of sludge treatment facilities at three Colorado Springs plants needing treatment systems. Plant 1 treated raw water of 8 turbidity units and 100 ppm TDS with alum, soda ash, and chlorine. A wastewater recovery basin was built to retain sedimentation sludge and filter washwater. Plant 2 treating a less turbid water, constructed recovery basins. Plant 3 recaptured supernatant from sludge and backwash water settling. Solids were processed on drying beds for landfill. St. Paul decided on recalcining lime and recovering filter washwater at their softening plant. $Mg(OH)_2$ was separated from $CaCO_3$ by carbonation and centrifugal classification. Waste solids are lagooned. The CO_2 from recalcining is used for chemical stabilization of the finished water and sludge recarbonation. Washwater is recycled to the sedimentation basins. Expected yearly results were: 9800 tons 92% CaO ; 330 tons excess CaO for sale; 9950 tons CO_2 ; 170 million gallons washwater recovered; sludge volume for disposal reduced by 83%; and reduced load to sewage treatment. In Minneapolis the waste plan included: alum regeneration; lime recalcining; CO_2 recovery; magnesium recovery; and hydrochloric acid production. Each handling problem is unique.

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WATER CONDITIONING PRACTICES

Evans, G.R., "Review of Experiences with Microstrainer Installations", Journal AWWA, Vol. 49, No. 5, pp. 541-549, May 1957.

Key Words: Filtration, Microstrainer

A report on the utility of microstraining for municipal and industrial water clarification. Advantages included: low initial outlay; small space requirements; low head loss; automatic operation; and low maintenance costs. Equipment and construction details, and operation and maintenance costs are provided. Equipment and construction details are provided for an installation. Operation and maintenance costs are estimated at \$1-1.50/million gallons, including power and backwash water charges. Four standard units are available. Efficiency depends on the formation of a thin mat of intercepted solids on the inner fabric surface. The strainer does not appreciably reduce true colloidal matter or color. Filter media apertures are 60, 35, and 23 u. A formula to select and size filtrability index, flow volume, speed drum and fabric area, and loss of head across fabric. Applications include: sole filtration process; pretreatment before filtration; filtration following flocculation and sedimentation; reduction of suspended matter in secondary sewage and industrial effluents; and prevention of waterborne parasitic disease.

Harris, R.H., "Use and Control of Polyelectrolyte Filter Aids in High Rate Filters", Paper Presented at 91st Annual Conference, American Water Works Association, Denver, Colorado. June 13-18, 1971.

Key Words: Turbidity, Filter aid

The application of filter aids in three Southeastern water treatment plants and a technique for operating and maintaining aid dosage levels. Filter aids have reduced primary coagulant dosages and produced longer filter runs and high quality filtrate. Headloss build-up and backwashing problems occur when aids are overdosed. A schematic of a filter aid feed system for polyelectrolytes is presented. A turbidity monitoring system utilizing a 90° scatter nephelometer type turbidimeter is detailed. Optimum filter performance is obtained in dual-media filters, with a coarse anthracite top and sand bottom, when 90 to 95 percent of the turbidity is removed in the anthracite portion and anthracite-sand interface turbidities are cyclically monitored. Data on raw water character, treatment conditions, and test results are enumerated for the three treatment facilities using this system.

Lees, Ronald D., "The Role of Polyelectrolytes in Water and Waste Treatment", Presented to the Manitoba Department of Health and Social Services, Winnipeg, Manitoba, Canada, March 15, 1971.

Key Words: Water treatment, Polyelectrolytes

This paper describes the utility and effectiveness of polyelectrolytes for filtration, sedimentation, and sludge dewatering applications. Ionic polymers attract electrically charged colloids, forming bridges between the suspended solids particles. This bridging action enhances settling and dewatering. The most ideal polymers are easy to use, heavily weighted, with excellent pH stability, wide dosage levels, slightly affected by sharp system character changes, and with the proper type and amount of functionality. Polyelectrolytes aid filtration by providing longer filter runs with cleaner filtrates. Polymers improve sedimentation by increasing tank capacities, producing cleaner effluents, and providing thickening and compaction of sludge blankets. Polymers have demonstrated usefulness in dehydrating settled sludge, filter cake, and centrifugation residues. Polymers prove effective as settling aids for the coagulation of phosphates from wastewater. The application of polymers as conditioning agents for flotation and vacuum filtration processes is discussed. On-site in-depth testing is required before the full-scale application of polymers at a facility.

Sexsmith, D.R., Savinelli, E.A. & Beecher, J.S., "The Use of Polymers for Water Treatment", Industrial Water Engineering, Vol. 6, No. 12, pp. 18-23, December 1969.

Key Words: Scaling, Flocculation, Dispersion, Polymers

This report reviewed the utility of polymers for flocculation, dispersion, and scale control. The four polymer types are natural, modified natural, vinyl, and condensation. Universally applicable polymers do not exist. The most important properties are molecular weight and charge. Molecular weight is related to bridging and adsorbing action. Functional groups influence the electrical charge to neutralize surface charges of colloidal particles. An overdose of a highly charged polymer could create electrical imbalance and act as a dispersant. A dispersant prevents particle agglomeration, bridging, and settling. Some polymer combinations reduce boiler tube or cooling tower incrustations and remove existing scales. Highly concentrated carboxyl groups and combinations of polymeric and complexing agents are best for scale control. Three case histories are discussed. A polymer-polyelectrolyte combination reduced deposit thickness in boiler tubes plugged with phosphate, lignin organic, catalyzed sulfite, and neutralizing amine scale. Cleaning and fuel consumption costs were reduced. A cationic polymer reduced a silt, iron oxide, and microbial slime scale in heat exchangers at an oil refinery. A combined polymer-sequestering agent reduced cooling tower scale at a foundry operation.

Williams, J.W., "Effect of Water Conditioning on Wastewater Quality", Journal AWWA, Vol. 60, No. 12, pp. 1329-1335, December 1968.

Key Words: Ion exchange, Sodium zeolite

This paper discussed chemical precipitation and ion-exchange softening of water. Types of hardness are described. Softening costs at filtration plants are as low as \$0.03/1000 gal/100 ppm hardness removed. Unit costs are higher for lime-soda when significant non-carbonate hardness is present. Savings of \$11.7¢/1000 gal/100 ppm hardness removed are estimated for soap, detergents, lyes, bleaches, shampoos, hand lotions, coffee, tea, fuel, washable clothing, linens, towels, and plumbing repairs. Soft water is more corrosive than hard water. Chemical precipitation softening equations are prepared. Ion exchange is preferable when: substantial non-carbonate hardness exists; waters contain less than 100 ppm hardness; low effluent hardness is required; sludge disposal facilities are not available; and small water volumes need softening. Regeneration of resins is by backwashing, ion replacement, and rinsing. Waste products are excess regenerant and hardness ions. Softening capacity is usually expressed as grains hardness as CaCO_3 removed/ ft^3 resin. Most economic salt usage is 0.3-0.5 lbs/1000 grains hardness removed. Wastewater reclamation may be feasible by membrane processes on waters of 1000 TDS. Other disposal methods are discharge to ocean outfalls, sewers, or deep well injection.

WATER TREATMENT PLANT WASTES

Review Articles

AWWA Book, "Water Quality and Treatment", McGraw-Hill, New York, N.Y. (1971), pp. 625-645.

Key Words: Sludge disposal, Residues

Chapter on the nature of water treatment plant residues, disposal techniques, by-product recovery, and aesthetic and legal aspects of the waste disposal problem. Residue sources include: aluminum and iron oxides, sands, silts, and organic matter from chemical coagulation processes; CaCO_3 , $\text{Mg}(\text{OH})_2$, and lime from softening by precipitation; filter backwash water; iron-manganese oxides; and spent activated carbon and ion-exchange regeneration brines. Chemical coagulation and filter backwash wastes have traditionally been discharged to watercourses, storm and sanitary sewers, sludge beds, and impounding basins or lagoons. Disposal methods for softening wastes by precipitation are similar. Ion exchange brines have been injected into the ground, discharged to watercourses, or evaporated. Reactions are given for lime recalcining, iron and alum recovery. Sludge discharged to watercourses may create sludge blankets which inhibit natural biologic activity, increase turbidity and stream color, and exceed state and federal water quality standards. Additional research is suggested.

Faber, H.A. & Nardozzi, A.D., "Disposal of Water Works Wastes", Paper Presented at Iowa Section AWWA Meeting, Des Moines, Iowa, (1971), 20 pages, (unpublished).

Key Words: Sludge treatment, Sludge disposal, Treatment alternatives, Research needs

Review of the development of treatment alternatives to process lime-soda and alum sludge and filter washwater. Waste discharge regulations for Iowa and the nation compared. Processes discussed included: settling or lagooning; drying beds; freezing; lime recovery; alum recovery, filter pressing, and chemical coagulation. Evaluation of magnesium carbonate as a recycled coagulant and the effectiveness of polyelectrolytes as primary coagulants, coagulant aids, and sludge conditioning agents. Research needs suggested were development of uniform reports on sampling, analysis, and waste categorization; investigation and application of new or modified physical and chemical liquid-solids separation processes; and more detailed investigation of by-product recovery technology. Demonstration is required on the utility of polymers, filter washwater recycling; and solid waste recovery for reuse or marketing.

Faber, H.A. & Nardozzi, A.D., "Water-Treatment-Plant Waste Disposal--Action Now!" Journal AWWA, Vol. 64, No. 10, Part 1, pp. 674-680, October 1972.

Key Words: Sludge treatment, Sludge production, Unit processes

Discussion of specific sludge and filter washwater wastes from water purification and softening facilities. Sludge production and handling were related to: sludge types; suspended and dissolved solids removal chemistry; raw water quality; qualitative and quantitative physical-chemical constituents; treatment plant efficiency; and sludge withdrawal methods. Potential correlations of raw and treated water parameters to sludge production are given. Other considerations include: problems in pumping and gravity flow; unit processes or process sequences under development to dewater or recover by-products. Two phases of work are described to establish uniform sampling, analysis, and categorization techniques for all types of water treatment plant wastes and evaluate polyelectrolytes for use as primary coagulants, coagulant aids, and sludge conditioning agents. Research needs, and recommendations are enumerated.

Faber, H.A. & Nardozzi, A.D., "Information Resource: Water Pollution Control in the Water Utility Industry", Report 12120 EUR for EPA, 169 pp., Nov. 1971, (For sale by Supt. of Documents, Washington, D.C.).

Key Words: Sludge disposal, Sludge treatment, Information clearing-house, Information resource

This report describes the accomplishments of a program conducted to organize, coordinate, and disseminate information on new or modified sludge treatment technology for water treatment plant wastes. The reliable control of these potential pollutants is of increasing importance with the enactment and enforcement of more stringent pollution control legislation. The report contains information on research, engineering, plant operation, and regulatory aspects of the problem. A Project Advisory Committee provided recommendations for development of information resources, and assisted the Research Foundation in structuring an information clearinghouse. The report describes current research activities and new approaches for characterizing and reducing water treatment plant waste volumes. A program was initiated to evaluate the applicability of polymers as primary coagulants, coagulant aids, and sludge conditioning agents. A Sub-Committee was established to prepare uniform sampling, analysis and categorization techniques for water utility sludges. Each program is in progress. Surveys were distributed to water utilities and regulatory agencies to provide information on sludge treatment methods and requirements. The AWWA Research Foundation plans the continuation and expansion of this centralized information resource program.

Hudson, H.E., "How Serious is the Problem?", Proceedings Tenth Sanitary Engineering Conference, Waste Disposal from Water and Wastewater Treatment Processes, University of Illinois, Urbana, Feb. 6-7, 1968.

Key Words: Recycling, Water sludge

Industrial and water consumption totals 150 and 360 tons/capita/year. Over 60 million tons/year of water and wastewater sludges (dry basis) are generated. Sludge loads from water treatment plants are 15 pounds/capita/year. The handling of waste quantities must be done to create equilibrium conditions with the environment. Detroit, Michigan recycles washwater and benefits by improved settling and filtration. Seasonally cleaned basins require separate treatment or holding facilities while continuous sludge removal units could discharge to sewers. Zeolite softening and electroanalysis brine streams have been diluted by discharge to streams. Calcining and reuse is suggested for chemical precipitation softening waste, with magnesium being separated or recovered. Clarification sludges can be vacuum filtered with lime conditioning. Alum recovery is practiced in Japan. Cationic polyelectrolytes may become effective as primary coagulants. Water treatment plant sludges would add a 10% solids loading to sewage treatment plants. The author concludes economic methods must be developed to recycle wastes.

Singley, J.E. & Black, A.P., "Water Quality and Treatment: Past, Present, and Future", Journal AWWA, Vol. 64, No. 1, pp. 6-10, January 1972.

Key Words: Water treatment, Process

This study reviewed past and present water treatment history and cited potential processes and control parameter refinements requiring further investigation and application. Water treatment design has been traditionally conservative. Some utilities have adopted: polymers for use as primary coagulants and coagulant aids; automatic monitoring and process control; and have instituted individual research programs. The time lag between process development and plant adaption must be decreased. Research considerations included: process optimization; development of new control methods and coagulants; place and extent of mixing; increased automation; development of new filtration media; the effect of tract minerals and organics; improving disinfection; and sludge disposal. The utility of recovering and recycling $MgCO_3$ at purification facilities is discussed. A 50 gpm pilot plant is evaluating this recycled coagulant for effectiveness in reducing color and turbidity at Montgomery, Alabama.

WATER TREATMENT PLANT WASTES

Committee Reports

AWWA Committee Report, "Purification Plant Waste Disposal", Journal AWWA, Vol. 45, No. 11, pp. 1225-1237, November 1953.

Key Words: Sludge disposal, Brine disposal, Filter plant wastes

Final committee report consisting of the following separate published reports: (1) "Lime and Lime-Soda Sludge Disposal," December 1957 Journal, page 1211; (2) "Brine Disposal From Sodium Zeolite Softeners," December 1947 Journal, page 1215; (3) "Disposal of Wash Water From Purification Plants," December 1947 Journal, page 1219; (4) "Lime and Lime-Soda Sludge Disposal", September 1949 Journal, page 819; (5) "Brine Disposal From Cation-Exchange Softeners", November 1949 Journal, page 829; (6) "Disposal of Wastes From Filter Plants and Coagulation Basins," 1953 Journal, page 1226. It was realized that each treatment plant has a problem that is probably unique to itself. Therefore, the desire of the members of this committee has been to present a report containing a general coverage of the subject, with sufficient references to guide anyone endeavoring to solve a specific problem to information applicable to that problem.

AWWA Committee Report, "Disposal of Water-Treatment-Plant Wastes", Journal AWWA, Vol. 64, No. 12, pp. 814-820, December 1972.

Key Words: Sludge treatment, Waste volume minimization

This study reviewed reclamation, handling, and disposal procedures for water treatment wastes and recommended areas requiring further research. Waste discharges to watercourses will be limited by strict pollution control legislation. Waste disposal processes should be incorporated into new treatment plant designs, for minimization of waste volumes, water reuse, and by-product recovery. Lime and alum recovery processes are described. Filter backwash recycling is discussed. Future research recommendations include: developing standard methods for sampling, analyzing, and categorizing wastes; waste quality minimization procedures; chemical and water recovery; waste quantity and character improvement through polymer utilization; and new disposal techniques.

Illinois Section Water Resources Quality Control Committee, "Water Treatment Plant Wastes", AWWA Annual Conference, March 19, 1970. (Unpublished.)

Key Words: Questionnaire, Waste characteristics, Filter plant wastes

Existing waste disposal methods for basin sludge removal and disposal and filter backwash disposal were evaluated through analysis of a questionnaire distributed to surface water and ground water treatment plants throughout Illinois. Data for types and quantities of wastes were compiled from six to nine month operating records and analysis of grab samples. Basin sludges varied in chemical, organic, and inorganic composition in relation to the processes employed as well as source of process water. Lime softening systems produced basin sludges rich in calcium carbonate and hydroxides of magnesium and aluminum. No generalizations could be drawn from any of the data with respect to any plant processes. Excluding the amount of lime required to remove hardness, all other attempts at correlations proved futile due to poor sampling techniques. Examinations of filter backwash water indicated solids release patterns exist. A relationship between suspended and settleable solids released and time for such release could lead to the optimization of backwash rates and times. The limited filter backwash data strengthened the need for more efficient and uniform techniques as well as creating interest in the proposition of higher solids loading per unit area of filter.

WATER TREATMENT PLANT WASTES

Characteristics of Wastes

Calkins, R.J., "Characterization of Chemical Sludges", Paper Presented at Annual Conference of ANWA, June 7, 1972, Chicago, Illinois. (Unpublished.)

Key Words: Filtration, Sludge character.

This paper relates sludge characteristics to the chemical process scheme and raw water quality. The methodology used is described. Twenty five water purification, softening, and combined sludges were studied in relation to settled solids concentration, filtration rate, and cake solids. General results included: iron coagulants provided more compact sludge than aluminum coagulants, with a Catfloc sludge the heaviest; increasing magnesium content adversely affects settleability and sludge compaction for iron and aluminum coagulant sludges; sludges from turbid water attain higher settled solids concentrations than sludges from low turbidity raw waters; and backwash solids settle to one-half the concentration as from the preceding settling unit. Specific resistance and filter loading are determined. Combined softening - purification sludges filter more rapidly than do pure coagulants. Sludge with specific resistance ($10 \times 10^7 \text{ sec}^2/\text{g}$ filter well. Filter backwash sludges exhibited poor filtering quality. Sludge can be characterized by volumetric techniques by evaluating settled solids in a graduated cylinder.

Cosens, K.W., "Water and Wastewater Treatment Plant Sludges", Presented at West Virginia Joint Section Meeting, American Water Works Association and Water Pollution Control Association, Wheeling, West Virginia, April 6, 1972. (Unpublished.)

Key Words: Sludge treatment, Disposal methods

Data are given for particle size and settling velocities of alum and iron flocs; sand, salt, and clay flocs; and softening wastes. Softening of surface water produces 3.5 lbs. dry solids/pound of hardness removed as CaCO_3 . Sludge treatment or disposal methods are: dilution, lagoons, sand drying beds, vacuum filtration, freezing, filter pressing, centrifugation, land disposal, recovery, and discharge to sanitary sewers. The Little Falls plant plans to thicken sedimentation coagulation sludge and settle washwater. Concentrated sludge is held, centrifuged, conditioned by lime and polymer, and presses with the cake used for landfill. Presses process 50 tons/8 hours. Portsmouth, Ohio, plans vertical basket centrifugation of alum sludge and land disposal. Columbus, Ohio, proposes recovering magnesium and lime from softening sludge in a 10 gpm pilot facility. Fremont, Ohio, plans centrifugation of softening sludge and land disposal in quarries or farm fields. St. Paul recalcines their lime sludge.

Gates, C.D. & McDermott, R.F., "Characterization and Conditioning of Water Treatment Plant Sludge", Journal AWWA, Vol. 60, No. 3, pp. 331-344, March 1968.

Key Words: Sludge treatment, Alum sludge

The purposes of this study were to develop methods to measure alum sludge character and to determine the relationship between dosage and specific resistance as a valid measure of polyelectrolyte effectiveness on dewatering. Important parameters were: total solids content; settleability; and filterability. Drain-effluent and in-place basin samples were tested. There was zone settling until compression occurred. The initial settling rate of sludge-liquid interface was related to the total solids concentration. The Buchner funnel method was modified to permit a valid comparison of polyelectrolyte effect on filterability. Specific resistance values were recorded. Sludge greater than 1% in solids exhibited non-Newtonian flow character. Sampling, collection, and testing methods to evaluate 4 polyelectrolytes are described.

Russelmann, H.B., "Characteristics of Water Treatment Plant Wastes", Proceedings Tenth Sanitary Engineering Conference, Waste Disposal from Water and Wastewater Treatment Processes, University of Illinois, Urbana, Feb. 6-7, 1968, pp. 10-20.

Key Words: Waste identification, Water treatment plant wastes

Water treatment plant wastes produce fewer problems than wastewaters from municipal sewage and industrial facilities because they are: less in volume; low in magnitude of pollution; and not a public health hazard. These are pollutants because; they contain damaging constituents; pollution control is more demanding; new techniques generate new problems; and stream use is competitive. Waste discharges create unsightly deposits, odors, hinder biological activity, deplete oxygen, interfere with photosynthetic processes, and are toxic. Raw waters contain organic, inorganic, and microorganism materials. Various alum and iron salts, chlorine, polyelectrolytes, lime, soda ash, and activated carbon are added. Coagulation sludge and filter washwater parameters including BOD₅, OOD, pH, total solids, volatile solids, total suspended solids, and volatile suspended solids are tabulated. Backwash water is discharged to storm drain and streams, lagooned, and recycled. The objective with ion-exchange brines is to minimize discharge concentrations and variations. Wastes from reservoir cleaning; deplete oxygen rapidly; reduce temperature sharply; release high turbidity and color; and create sludge. Waste treatment must be considered in future designs.

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WATER TREATMENT PLANT WASTES

Treatment of Filter Washwater

Hall, H.R., "Disposal of Washwater from Purification Plants", Journal AWWA, Vol. 39, No. 12, pp. 1219-1223, December 1967.

Key Words: Sludge treatment, Waste characterization, Disposal methods

This report outlined waste character, quantity, effects, disposal methods, and legal difficulties considerations for water treatment sludges. Washwater turbidities of 2000 ppm have declined to 50-100 ppm during backwash. A one hour detention period can lower turbidity to 40-50 ppm. Pre-chlorinated supernatant is practically free of coliform organisms. Methods to effectively determine BOD are not included in Standard Methods. Each plant individually must determine waste quantity based on sludge character. Wastes contain silt and chemicals. Discharge to streams can cause discoloration, but public health is not jeopardized. Odors can emanate from stored sludge. Disposal methods include: discharge of washwater and sludge wastes to streams without treatment; lagooning of washwater and sludge with supernatant discharged to stream or returned to the plant inlet; washwater and sludge to sewers; and pumping to a reservoir. Experiments were conducted on settling filter washwater and basin sludge. The City of Laurel enjoined suit on an upstream facility discharging waste to river, charging quality degradation due to sludge disposal. The need for further definition of pollution effects, health hazard, and pre-chlorination of washwater to decrease bacterial content was established.

Hirsch, A.A., "Backwash Investigation and a Proposed Simple Uniformity Control", Journal ANWA, Vol. 60, No. 5, pp.570-585, May 1968.

Key Words: Temporal distribution, Backwash

This study investigated backwash characteristics, washing process dynamics, effect of bed structure, and theoretical considerations for filter design. Suspended solids concentrations of backwash samples were taken at the troughside bottom, intertrough median, a corner, and the sewer. Sampling intervals were 1/15 seconds. Testing at Shreveport, Louisiana, showed washwater streaks toward trough edges. Uniform washwater removals over the entire filter surface were achieved utilizing nozzles 6 inches on center above the filter bed. Short-circuiting in backwash must be avoided. A measured velocity profile showed that washwater is wasted, operation and maintenance problems begin, and uneven filtering occurred following non-uniform washing. The area under backwash curves of suspended solids concentrations versus time gives sediment removed. Peak backwash concentrations decay logarithmically. Formulations are presented for determining decay and washing efficiency. Inversely graded beds yielded broader backwash curves than traditional filters. The report showed: most thorough washing occurred at the bottom of the vertical walls of trough; draw-off members can be classified according to simple geometric counterparts; and filter beds wash unevenly due to the directional influence of the washwater troughs.

Pallo, P.E., Schwartz, B.J. & Wang, L.K., "Recycling and Reuse of Filter Backwash Water Containing Alum Sludge", Water & Sewage Works, Vol. 119, No. 5, pp. 123-125, May 1972.

Key Words: Recycling, Filter washwater

The purpose of this article was to investigate the feasibility of directly recycling filter washwater together with alum sludge to the flash mixer of a conventional water treatment plant and to study the possible effect of recycle on effluent quality and sedimentation operation. Composite samples of filter backwash were jar tested. Physical and chemical parameters were determined by Standard Methods and listed. A holding basin was used to equalize the filter backwash water before the washwater with alum sludge was returned to the flash mixer. Data showed: backwash water is an effective coagulant aid up to 40% recycle in reducing color and turbidity; a pH drop caused by recycling aided alum coagulation; a 2% recycle reduced alum dosage requirements from 1.2 to 1.0 grains/ gallon while maintaining efficiency; and recycling yielded a denser and smaller floc settling at a faster rate. Based in Imhoff cones, 95% of the sludge was precipitated in 20 minutes by recycling compared to 35 minutes without recycling. Recycling backwash avoids stream pollution and reclaims water for reuse.

Van Reuth, A.G., "Treatment and Disposal of Sedimentation Tank Sludge and Sand Filter Backwash Water, Van Bibber Water Treatment Plant, Edgewood Arsenal, Maryland", Personal Communications, Dec. 1970.

Key Words: Alum sludge, Centrifugation, Dewatering processes

Several treatment processes were evaluated for concentrating the predominantly aluminum hydroxide sludge at this purification plant with a design capacity of 4.0 mgd. Laboratory tests were conducted on potential dewatering methods including vacuum filtration, sand filtration, evaporation and decanting (lagooning), freezing, chemical treatment, and centrifugation. Evaporative lagooning with decantation and centrifugation with chemical treatment were found to warrant further investigation in this application due to their practicality and efficiency. Field demonstration tests on waste conditioned with synthetic organic polymers were made using a Dorr-Oliver Merco Bowl Long Bowl Centrifuge. These tests showed that centrifugation was the most economical treatment process for the handling of the sedimentation tank sludge and sand filter backwash water. The recommendations from the study have been adopted and now constitute the basis for design and construction of new facilities which are scheduled for early completion at the Van Bibber Plant. The construction costs are estimated at \$180,000 and annual operating and maintenance costs are estimated at \$29,000. Van Reuth and Weidner, Inc. will provide the engineering services.

Westerhoff, G.P., "Action Now in Filter Plant Washwater Treatment", Paper Presented at Spring Meeting of the New York Section of the American Water Works Association, Syracuse, New York, April 6, 1972.

Key Words: Sludge treatment, Alum recovery, Waste reduction

This report outlines a two phase program to evaluate alum coagulation sludge and filter washwater treatment processes. Alum sludge is difficult to dewater. Sturgeon Point treatment includes: aeration, chemical addition, mixing, flocculation, and sedimentation, filtration, pH adjustment, fluoridation, and chlorination. Plant scale design data must be developed for wastes. Alum sludge solids, consisting of $Al(OH)_3$, organic and amorphous materials, vary from 50-200 lbs/million gallons of water produced. A composite backwash analysis showed 65 lbs solids/million gallons filtered water. Basic proposed facilities include: sludge and washwater holding tanks, thickener-clarifier, waste lagoons, centrifuge, filter press, half-scale alum recovery plant, and backwash recycling equipment. Alum recovery is expected to reduce waste solids to one-sixth their original volume and produce a reuseable alum. The recovery process includes: thickening of sludge, acidulation with H_2SO_4 , thickening-separation, filter pressing, feed systems, control equipment, recovered alum storage, and recycling, all on batch or continuous bases. Preliminary work showed no iron or color build-up in reclamation. The study programs aim to: identify physical-chemical waste character; evaluate liquid-solids separation with and without aids; determine feasibility of alum recovery; evaluate recovered alum effects on plant operation; and reduce backwash water flow quantities.

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WATER TREATMENT PLANT WASTES

Treatment of Sludges

Chemical Recovery Processes

Roberts, J.M. & Roddy, C.P., "Recovery and Reuse of Alum at Tampa", Journal AWWA, Vol. 52, No. 7, pp. 857-866, July 1960.

Key Words: Sludge treatment, Alum reclamation

Alum reclamation proved economically and technically feasible at Tampa, based on laboratory tests. The facility employed alum coagulation of water containing varying organic color and mineral content. One commercial ton of alum applied equals 525 pounds of $Al(OH)_3$ sludge, 1.9 pounds of H_2SO_4 is needed to react with 1.0 pound of $Al(OH)_3$. Successful laboratory work led to pilot plant studies. Two pilot plants were built to evaluate maximum thickening conditions. A third plant was constructed to treat raw water with reclaimed alum. The resulting floc was collected, thickened, and reacted with concentrated H_2SO_4 to produce $Al_2(SO_4)_3$. Alum, recycled 8-10 times, showed no interference with acid-insoluble material or any change in chemical or bacteriologic water quality. A plant scale study of commercial versus reclaimed alum was made. Proposed facilities included: a 20 mgd conventional settling basin, equipped with sludge collectors, to concentrate sludge; a thickening basin; and sludge reaction tank where H_2SO_4 is added and mixed. Reclaimed alum will be recycled to the raw water.

Black, A.P., Shuey, B.S. & Fleming, P.J., "Recovery of Calcium and Magnesium Values from Lime-Soda Softening Sludges", Paper Presented at Ninety-First Annual Conference American Water Works Association, Denver Convention Complex, June 13-18, 1971.

Key Words: Water treatment, Calcining, Magnesium carbonate

The carbonation of softening sludges containing magnesium hydroxide produces a selective dissolution of the magnesium precipitate to its carbonate form. A tabulation of liquid sludge volumes and calcium carbonate, carbon dioxide, and magnesium hydroxide production is presented for Dayton. Carbon dioxide from lime calcination is utilized to carbonate sludge from settling basins. The mixture is thickened and the calcium carbonate precipitate withdrawn for centrifugation. Lime recovery reduces chemical costs, waste disposal problems, and produces excess lime for sale and carbon dioxide for carbonation. A pilot plant was constructed to produce magnesium carbonate on a batch basis. The process includes carbonation of softening sludge, settling or filtration of calcium carbonate solids, and heating and aeration of the magnesium carbonate solution. The major reactions are listed. The hydrated carbonate precipitate is vacuum filtered, dried, and bagged. Filtrate is recycled to storage tanks for subsequent recovery. Data are provided from the pilot operation. The process is adaptable to waters with high clay turbidities with the addition of a flotation step following recarbonation. Potential magnesium carbonate production capacities and estimated revenues are calculated for 20 cities.

Fischer, A.J., "Discussion on Pontiac Recalcining Plant", Journal AWWA, Vol. 40, No. 4, pp. 465-466, April 1948.

Key Words: Calcium carbonate, Recalcining

The recalcining of lime has been practiced in the heavy chemical and paper pulp industries for several years. In the water treatment industry, lime reclamation has been economical when burning 25 tons CaO/day in conventional rotary kilns. The Fluo Solids Calciner recalcines dry calcium carbonate sludge to an air fluid suspension. Fluidized suspension burning has been used in the petroleum industry for roasting ores. Sludge from the precipitates is centrifuged, conditioned with soda ash and dried sludge, passed to Raymond flash drier, and burned in the Fluo kiln. The kiln temperature is 1750°F with the CaO pellets discharged at a temperature of 300°F. The advantages of this system are compactness, low installation cost, low operation and maintenance costs, and dust free operation.

Gordon, C.W., "Discussion on Pontiac Recalcining Plant", Journal AWWA, Vol. 40, No. 4, pp. 466-467, April 1948.

Key Words: Calcium carbonate, Recalcining

The C-E Raymond Flash Drying System rapidly dries materials in the fine to granular form. The complete conversion of a dewatered centrifuge calcium carbonate cake to a dried and preheated powder requires a few seconds. The calcining furnace decomposes calcium carbonate to quicklime and collects the finished product. The positioning of the oil burners is critical for short duration complete calcining. At Marshalltown, Iowa, and 80% lime content is reclaimed out of a theoretical 84% content. Coagulation with the reclaimed lime is excellent. Furnace temperatures are traced throughout the systems. Flash drying is of the two-stage, counter-flow type. At Marshalltown, one ton of high quality finished lime is produced with a fuel consumption of 9.66 million BTU. The power consumption is 60 kwhr/ton finished lime.

Sowden, H.H., "Lime Recovery from Water Softening Sludges", Journal AWWA, Vol. 33, No. 4, pp. 741-748, April 1941

Key Words: Sludge treatment, Calcining, Vacuum filtration

This study discussed experimental calcining of softening sludge to produce a reusable lime product and a method to determine percent solids in the sludge. Turbid matter is removed by alum coagulation in separate basins before softening. Coagulant aids interfered with vacuum filtration dewatering. Filtration rates of 2010#/ft²/24 hr were achieved on unconditioned precipitator sludge. A 5% CaO solution increased dewatering while powdered coal, carbon dioxide, bentonite, and heat treatment were not effective. Savings are realized in the purchase of new lime and sludge disposal costs. Tabulations of lime analyses are presented for calcination experiments. A 2-5% solids softening sludge from the precipitators is thickened by natural subsidence and mechanical means to 20-30% solids. An experimental vacuum filter concentrates solids to 60%. Air drying reduces moisture content to 10%. Sludge is calcined in a muffle furnace at 2000°F till completely burned. A formula, based on weight and volumetric considerations, is derived to determine percent sludge solids. Excess lime should be recovered. Economic feasibility depends on: new lime cost; calcining expenditures; and sludge disposal criteria.

Swab, R.H., "Pontiac Recalcining Plant", Journal AWWA, Vol. 40, No. 4, pp. 461-464, April 1948.

Key Words: Water softening, Calcining

The City of Pontiac incorporated provisions to dry 28 tons/day of calcium carbonate sludge and recover the lime at their softening facility. The three stage operation included: dewatering, classifying, and rejecting a portion of the magnesium and other impurities by continuous centrifugation; drying in the Raymond Flash Drying System; and recalcination by exposing dried material to a temperature of 1900°F. The carbonate precipitate is transported to slow-speed stirring slurry receiving tanks. Concentrated slurry is discharged to two continuous centrifuges. The magnesium and other impurities are passed to the sanitary sewer and the calcium carbonate is conditioned prior to flash drying. The flash drier is composed of a cage mill and blower. Dried material is calcined in a furnace with the CaO sent to storage bins. The maximum operating cost per ton (CaO) is \$7.95.

Kinman, R.N., "Magnesium Carbonate for Water Treatment", Presented at First Sanitary Engineering Seminar, Central Ohio Section, ASCE, March 27, 1972, 11 pp.

Key Words: Magnesium carbonate, Surface water, Drum process wastewater

This compared MgCO₃ as a coagulant for Ohio surface waters and variable drum process wastewater with alum and lime. A pH titration curve using Ca(OH)₂ was run on four surface supplies. The lime dose to produce a pH of 11.3 was added to 500 ml samples and mixed at 100 rpms for 1 minute and 30 rpms for 20 minutes. Samples were settled for 20 minutes. Five minutes time was generally efficient for the rapidly settling Mg(OH)₂ floc. Physical-chemical data are tabulated for different chemical doses on samples from the Ohio River, Licking River, Little Miami River, and Muddy Creek. Composite samples from steel drums were tested. These wastes include NaOH, detergents, sanitary sewage, oil, or anything that can be shipped by drum. The pH was 12.2 with a high COD value. A pH of 11.3 was attained by using HCl. Mixing was at 100 rpms for 3-5 minutes and 30 rpms for 20 minutes settling. Physical-chemical data are tabulated for coagulation of drum processing wastewater. MgCO₃, hydrolyzed with lime, effectively removes color, turbidity, COD, and other impurities. Flocculation and settling require less time than alum and could alleviate sludge disposal problems. Economic, operational, plant instrumentation, and efficiency evaluations are being made on pilot and plant scale basis in Montgomery, Alabama.

Thompson, C.G., et al, "Magnesium Carbonate - A Recycled Coagulant", Journal AWWA, Vol. 64, No. 1, pp. 11-19, January 1972.

Key Words: Magnesium carbonate, Modified technology

This study described the development of a coagulant system that effectively reduced organic color and turbidity and eliminated major sludge disposal problems. A low-cost source of $MgCO_3$ is under development. The major process reaction chemistry is described. The jar test parameters examined were coagulation pH, forms of alkalinity and hardness, settled water color and turbidity, electrophoretic mobility, residual magnesium, stabilized water character, and visual floc properties and settling rates. Type, grade, and preparation of materials used are described. A filter photometer is utilized for measuring color and turbidity and a zeta meter for electrophoretic mobility. Jar testing procedures are outlined. Laboratory separation of carbonated sludge containing soluble $MgCO_3$ and insoluble $CaCO_3$ and clay is accomplished by filtration through Whatman No 40 paper. Linear regression analyses of $MgCO_3$ dosage with color and turbidity were made. The heavy magnesium hydroxide floc increases present plant capacity. Recycled $MgCO_3$ was as effective as new $MgCO_3$.

Thompson, C.G., Singley, J.E. & Black, A.P., "Magnesium Carbonate: A Recycled Coagulant-II", Journal AWWA, Vol. 64, No. 2, pp. 93-99, February 1972.

Key Words: Magnesium carbonate, Coagulant recovery

This article suggested the utility of magnesium carbonate to remove organic color and turbidity at water purification plants and alleviate sludge disposal problems. A linear regression of $\log MgCO_3 \cdot 3H_2O$ versus pH is shown. Chemical treatment costs depended on CaO required for pH control; CO_2 to solubilize $Mg(OH)_2$ in the sludge and reduce high pH of treated water; and make-up $MgCO_3$. Lime recovery can supply quicklime and CO_2 . Cost curves are prepared. Cost data are tabulated for 17 natural waters including Atlanta, Baltimore, and Washington. A linear correlation existed between electrophoretic mobility and residual turbidity. A significant relationship was shown between particle mobility and residual turbidity when alum was used as a coagulant aid. The new treatment should remove and disinfect bacteria and viruses. A contact time of 4 hours and pH of 11.0-11.5 should be sufficient for disinfection. An equation for minimum $Mg(OH)_2$ as $MgCO_3 \cdot 3H_2O$ was determined based on water color, turbidity, total alkalinity, and total hardness. Carbonation does not release color in waters of 150 or less color units. A more elaborate recovery process or wasting of recovered solution is necessary on highly colored water. A flow diagram is prepared. Pilot and plant scale work is underway at Montgomery.

Vahidi, I., "Recovery of Waterworks Sludge", Journal of the Institution of Water Engineers, Vol. 12, No. 3, p. 211-212, May 1958.

Key Words: Biological methods, Alum recovery

Trivalent metallic ions such as Al^{+3} and Fe^{+3} neutralize negatively charged colloids causing particles to coalesce. The dumping of alum sludge on land makes it worthless for agricultural purposes. Fundamental research is aimed at studying the sludge nature and the way the coagulant is found to coagulate water. The method of investigation includes: study of nature and quantity of sludge produced in water treatment plants; treatment of wet sludge obtained by biological methods such as aerobic digestion and anaerobic digestion followed by aerobic digestion; and chemical treatment of oxidation followed by extraction with acid. Planned laboratory testing to aid in the control of digestion and alum recovery are: fixed and volatile solids analyses on raw sludge and digester samples; pH; Al_2O_3 determination by gravimetric method following acidification and paper filtration of sludge; and spectrophotometric analysis of iron. Preliminary tests show anaerobic digestion of alum sludge improves recovery operations.

Vahidi, I. "Recovery of Waterworks Sludge-II," Journal of the Institution of Water Engineers Vol. 12, No. 7, pp. 491-492, November 1958.

Key Words: Digestion, Alum recovery

Water purification sludge can either be dewatered, dried, and disposed of cheaply or the coagulant can be reclaimed for reuse with final disposition of the sludge commercially if a market can be found. Raw sludge at the Thockley Filtration Plant is slightly alkaline and odorous following the establishment of anaerobic conditions in lagoons. The sludge contains organic matter, humic acid, aluminum hydroxide (40% Al_2O_3) and ferric hydroxide (4% Fe_2O_3). Digestion was studied using 2 liter batch samples of raw sludge and 2 liter samples of digested sludge. The digested sludge is treated with H_2SO_4 with the mixture filtered through paper. Recovered alum data is tabulated. Laboratory work showed anaerobic digestion of alum improved alum recovery. A potentially applicable solution is the aeration of the sludge in the presence of certain bacteria species. Laboratory-bench scale and aeration tank experiments are planned along this line.

Vahidi, I., and Isaac, P.C.G., "Recovery of Water Works Sludge", Journal of the Institution of Water Engineers, Vol. 14, No. 6, pp. 454-458, October 1960.

Key Words: Centrifugation, Alum recovery

This paper described the laboratory investigation of alum recovery for water works clarification sludges. The purification sludge character includes: aluminum hydroxide; peat; algae; silt; and organic matter. The acidification of insoluble aluminum hydroxide recovers an alum solution and greatly reduces settling time and final volume of the settled sludge. Part of the precipitated organic color and iron salts can be built up in the recovered solution. In the laboratory, a 1.5-2.5% sludge solution was acidified and centrifuged. The centrate, reclaimed alum, was used for coagulation. A 60-65% recovery at pH of 3 had the best relative efficiency. An average yield of 1.5 tons of aluminoferric (14% Al_2O_3) is produced for consuming one ton of 98% sulfuric acid. This wet alum recovery process reduces sludge volume for disposal. Costs are considered. The total treatment includes: transporting 1.5-2.5% sludge solution to collection tanks; acid-treatment system; recovered alum separation by centrifugation; pumps, piping, and valves for recirculation of recovered supernatant; solution-storage tanks; and drying beds for the remaining sludge.

WATER TREATMENT PLANT WASTES

Treatment of Sludges

Dewatering Processes

Albertson, O.E. & Guidi, E.J., "Advances in the Centrifugal Dewatering of Sludges", Water & Sewage Works, Vol. 114, R.N., pp. R142, 1967.

Key Words: Centrifugation, Machine variables, Process variables

This study outlined the utility of centrifugation to treat sanitary and industrial wastes. An early history of perforated and inperforate basket, solid-bowl, and disc-valve centrifuges is presented. Conical centrifuges classify and dewater, cylindrical units recover fine particles in clarification, and cylindrical-conical devices are most suitable for clarification and maximum solids concentration. Solid bowl centrifuges are described. Machine and process variables are discussed. Machine variables include: bowl design with length to diameter ratio and bowl angle; bowl speed; pool volume (depth); conveyor speed; and pitch. Process variables include: feed rate; solids character with particle size and density; feed consistency; temperature; and chemical aids. Recovery is improved by increasing bowl speed and decreasing conveyor speed. A test program was run on raw primary and secondary digested sludge; pulp and paper wastes; and water softening sludges. Centrifugation increased solids concentration to 53-57% and recovery 79-93% for water softening waste. Tabulations are made for recovery-concentration data on tested wastes. Centrifugation advantages are listed.

Crook, J., "A Study of the Dewatering of the Cincinnati Water Treatment Plant Sludge by Centrifugation", Thesis Presented to Department of Civil Engineering, Division of Graduate Studies, University of Cincinnati for Master of Science, 1969, 95 pp.

Key Words: Centrifugation, Sand drying beds

The utility of centrifuging and sand-drying coagulation sludge in laboratory scale unit is examined. A literature review of sludge disposal techniques is prepared. A history of centrifugation including types, machine and process variables, economics, and advantages is presented. Sludge from the Cincinnati water treatment plant is evaluated. Laboratory and analytical methods are enumerated for sludge collection and storage, sample preparation, centrifugation equipment and techniques, drying beds, and polymer addition to the waste. The pH, COD, raw sludge solids concentration, settling analyses, centrifugation of raw sludge with and without polymer aids, centrate suspended solids removal, and sand drying bed efficiency are evaluated. Cake solids concentrations and centrate recovered increase with centrifugation speed and detention time. Presettling wastes before centrifugation appeared beneficial. Drying rates were comparable for raw and centrifuged sludge. Bench-scale centrifugation testing and drying bed development studies are recommended.

Keith, F.W., "Dewatering of Water Treatment Alum Sludge by Centrifugation", Paper Presented at 21st Annual Meeting of Pennsylvania Section AWWA, Pittsburgh, Pa., June 24-26, 1969 (Unpublished).

Key Words: Centrifugation, Basket centrifuge

This study described the utility of an imperforate bowl basket centrifuge to effectively dewater alum sludges. Imperforate conveyor centrifuges can produce a 60 percent lime sludge solids cake while selectively classifying magnesium hydroxide. The bowl basket centrifuge can be operated continuously with cyclic cake removal and adaptability to feed solid quality changes. The unit is automatable, requiring no coagulant and creates the least degradation of delicate alum hydrogel floc. Studies in England and the United States indicated 0.5 to 1.5 gpm of sludge is produced per mgd of plant capacity. Regression analyses were performed using sludge concentration, turbidity, centrifugal field residence time, and centrifugal acceleration data. Cake concentration depended on sludge compactability and centrifugal field residence time. A potential flow diagram to handle sedimentation tank sludge and filter washwater is presented. Recoveries of 90 to 98 percent were achieved at Pickering Creek Water Treatment Plant with this centrifuge.

Townsend, J.R., "What the Wastewater Plant Engineer Should Know About Centrifuges/1", Water and Wastes Engineering, Vol. 6, No. 11, pp. 42-44, November 1969.

Key Words: Centrifugation, Operating variables

This article described types of centrifuges and operating variables to be considered in their selection. Centrifuges clarify and classify solid-liquid slurries and separate liquids. Important factors are effective and theoretical capacity. Effective capacity is the slurry volume of a fully loaded centrifuge divided by the time to remove one-half the suspended particles. Theoretical capacity is an areal dimension of the gravity settling tank providing separation equivalent to centrifugation. Selection of a unit depends on solid removal requirements, shutdown time, and cost. The three best types of wastewater applications are the basket, disc, and continuous discharge decanter. A nozzle discharge centrifuge is most suitable for water treatment plants. Tests were run on a municipal activated sludge. The suspended solids recovery was plotted against the feed flow rate/theoretical capacity for three units. The disc centrifuge was the lowest cost machine per unit of capacity, but maximum sludge concentration was achieved in the basket type centrifuge. Centrifugation capabilities including: bowl diameter; flow rate; feed solids; discharge solids; temperature and pressure ranges; speed; gravity forces; motor power; and particles removed are tabulated for four machines.

Townsend, J.R., "What the Wastewater Plant Engineers Should Know About Centrifuges/2", Water and Wastes Engineering, Vol. 6, No. 12, pp. 35-37, December 1969.

Key Words: Centrifugation, Machine variables

The article outlined operating and cost factors, selection rationale, maintenance procedures, and applications for centrifugation. Operating factors included: maximum flow estimation; liquid requiring clarification; type and present solids concentration; system pressures; chemical conditioning; screens; and preconditioning equipment. Cost factors were: installed equipment cost; interest on money; amortization expenditures; plant space requirements; power; operation and maintenance needs; down-time; and standby equipment for 100% operation. An ideal centrifuge is described. Practical parameters considered were maximum allowable solids in effluent; moisture content of solids; space requirements; available capital; gravity forces and speed effect on effective capacity; liquid depth; length to bowl diameter ratio; and volumetric capacity. Each centrifugation application must be examined on its own merits. Items require checking. These are: bearing lubrication; power consumption; line voltage regulation; vibration limits; visual inspection; and unusual noises and odors. Inspection intervals are once each six months. Paper mill, municipal, refinery, steel mill, and water treatment plant wastes are tabulated for solid-bowl scroll, disc-type nozzle, and solid-bowl basket machines.

Clark, E.E., "Water Treatment Sludge Drying and Draining on Sand Beds", Water Quality Office, EPA, Research Grant 17070-DZS, and Research Fellowship 1-F1-WP-26-453-01, Report No. EVE24-70-4, August 1970.

Key Words : Sludge treatment, Sand beds

The objectives of this study were: define chemical-physical properties of wastes; assimilate technology from other disciplines for use; develop non-destructive moisture or solids content measurement methods; develop experimental apparatus and methods for studying sand bed dewatering; determine applicability of sewage sludge predictive formulations for water plant wastes; and apply results to engineering design. Information is provided on the problem background, historical development, theoretical consideration; materials and apparatus; methodology; and results. Sludge from alum coagulation with and without iron removal and activated carbon addition and lime-soda ash waste are tested. The study showed: chemical properties varied widely; drying and drainage accounted for majority of water removal; drainage times and drying durations can be predicted; moisture gradient is constant during dryings; and gamma-ray attenuation is applicable to sludge drying studies. Research and design recommendations are made.

Gauntlett, R.B. and Packham, R.F., "The Dewatering of a Clarification Sludge on Drying Beds", Journal of the Institution of Water Engineers, Vol. 26, No. 4, pp. 185-200, April 1972.

Key Words : Sludge treatment, Water treatment, Water purification, Clarification sludge, Sand drying beds

Eight experimental sludge drying beds at the Godley Works of the Manchester Corp. Water Dept. were used to compare a coarse and filter grade sand support medium as a cheap alternative to wedge wire, with the essential features of wedge wire bed operation being retained. The following conclusions resulted. Drying beds of suitable construction effectively dry waterworks clarification sludge during months when evaporation proceeds at a reasonable rate. The cost of such beds can be minimized by the use of a suitable grade of sand as an alternative to more expensive forms of drainage media, but some means of controlling the drainage rate is essential, unless polyelectrolytes are used. Translucent covers on the beds during all except the summer months is advantageous, and some saving in time and cost is possible by "layering" the sludge, although this practice leads to deterioration in drying performance. The main disadvantages of this sludge drying method are the very slow drying rate during the winter months and the large land area required. The drainage phase of the drying process is unaffected by seasonal climatic changes in a covered bed, and the possibility of using drainage alone, aided by polyelectrolytes, as a preliminary to some other sludge drying process should not be over-looked.

McWain, J.D., "Dewatering by Lagoons and Drying Beds", Proceedings Tenth Sanitary Engineering Conference, Waste Disposal from Water and Wastewater Treatment Processes, University of Illinois, Urbana, pp. 63-76, February 6-7, 1968.

Key Words : Lagoons, Sand drying beds, Asphalt-paved beds

This study presented observations, analyses, and investigations on: drying bed dewatering of aerobically digested sewage sludge; and lagoon and drying bed dewatering for upflow clarifier sludge from water treatment plants. Handling and disposal options for aerobic sludge included centrifugation, air flotation-vacuum filtration, and drying beds. Sand drying beds dewatered sludge by draining and evaporation. Shallow loaded beds dewatered rapidly with solids concentration times inversely proportional to initial bed depth. Evaporation was independent of bed depth. A homogeneous sludge concentration of 25% reduced volume by 85%. Dewatering on asphalt-paved beds produced a 20% sludge content of the initial volume. Clarification sludge from the Shoremont and Wolcott Plants was tested for lagoon and drying bed dewatering. Core samples from the lagoons showed this method unable to produce a 20% sludge. Pilot testing was initiated. Temperature, relative humidity, sand size, drainage time, drying time, total dewatering time, and final filtrate suspended solids concentrations are tabulated. A 1% sludge required 100 hours to produce a 20% cake with a filtrate of 240 mg/l suspended solids. A bed loading of 0.784 pound drying solids /ft² was needed. A 1.0 mm effective grain size was unsatisfactory for sludge dewatering.

Nebiker, J.H. & Adrian, D.D., "Cost Evaluation of Sand Bed Dewatering and Drying of Wastewater Sludges", Filtration and Separation, May/June 1969, 4 pp.

Key Words: Dewatering, Drying, Sand beds, Digital computer simulation

Approximately 72% of U.S. plants use sand beds to provide filtration by gravity dewatering and drying by evaporation. Little research has been directed to optimize design. This paper presents a rational formulation, or simulation, to describe sand bed operation based both on dewatering and drying processes. Independent formulations are presented for dewatering and drying. Drying rates are dependent on moisture content. A sludge dewatering-drying model is provided with initial constraints on: initial solids content; specific resistance; coefficient of compressibility; drying intensity; depth of sand and supporting media; and quantity of sludge produced each day. Boundary conditions for method of operation were sludge depth applied and final moisture content desired. Cost criteria included: land; construction of sand beds; maintenance; periodic repairs; salvage land value; and application and removal of sludge. Cost data are developed for different conditions. Digital computer simulation is applied. A method to optimize application depth for sludge and predict costs by simulation is shown.

Ralph, B. Carter Company, "Carter Automatic Belt-Filter Press", Technical Publication 4 pp.

Key Words: Dewatering, Filter press

This article describes the design principles and general operation of a filter press to dewater municipal and industrial wastes. The filter media is a multi-composition coarse mesh fabric. Polymers bridge the solid particles and accelerate dewatering in a pre-treatment sequence. The pressure for filtration is adjustable. Maximum pressure should be the point where sludge cake is retained on the filter belt and floc particles are not broken. Destroyed floc particles can pass the fabric or clog the filtration media. Equations describe dewatering in the drainage, press, and shear zone. Industrial sludges and twenty municipal sludges were dewatered by filter press in Germany. Data are tabulated for raw sludges, primary digested sludges, and mixed digested sludges from primary and secondary sewage treatment. These data include: sludge and presscake moisture content; water removed; sludge; and dry solids throughout; flocculant cost; power consumption; attendance time; and total operating cost. In England, data were tabulated for domestic and industrial waste, including pharmaceutical and brewery waste. Limited cost data compares filter pressing to sand bed drying and vacuum filtration of specific wastes.

Logsdon, Gary Steward, "The Mechanism of Water Plant Sludge Dewatering by Freezing", Private Communication, March 1971.

Key Words: Freezing, Sludge

An investigation was carried out to determine the mechanism by which water treatment plant sludge is dewatered upon freezing. A review of literature revealed that a limited amount of theoretical work had been done on this topic in sanitary engineering. However, extensive literature on soil freezing and sea water freezing was available, and it proved useful in understanding what happens when sludges freeze. Experiments were planned so that there would be similarities between sludge freezing tests and earlier work in other fields. Sludge samples were frozen by lowering them into an antifreeze bath. Thus freezing velocity could be controlled and comparison of sludge freezing and soil freezing research could be made.

Logsdon, G.S. & Edgerley, E., "Sludge Dewatering by Freezing", Journal AWWA, Vol. 63, No. 11, pp. 734-740, November 1971.

Key Words: Freezing, Water-solids separation, Sludge dewatering

Freezing tests on laboratory hydrous alum and ferric sludges and water treatment plant sludge are described. Sludge-freezing and soil-freezing literature is reviewed. Conclusions on sludge freezing speed, freeze length, thaw period, and solids content are made. Freezing changes are irreversible. Factors influencing soil-frost heave are enumerated. Data relates freezing speed to sludge dewaterability for test sludges. Settled volume concentrations of frozen-thawed sludge were one-half to one quarter of unfrozen settled volumes. Macroscopic or microscopic migration of solids particles is required for good water-solids separation and dewatering. Flash freezing is ineffective. Polymers that reduce sludge specific resistance can increase the gross-solids migrations during freezing. Freezing speeds of 60 mm/hr appear effective. Polymers can increase the freezing speed. Compressive forces are not necessary for good dewatering of frozen sludge. Spray nozzles should spread thin layers of sludge on frozen sludge beds for efficient natural freezing.

Fulton, G.P., "Appendix A, Vacuum Filtration of Water and Sewage Waste Sludge", Private Communication, March 1971.

Key Words: Vacuum filtration, Alum sludge

The present Town of Yorktown sewage treatment plant is located reasonably close to the general area proposed for the new Amawalk water treatment plant. Because of the proximity of the two sites, it was thought advisable to investigate the possibility of disposing of the alum sludge wastes from the water treatment plant along with the sewage plant sludge. The sewage treatment facility is a high-rate trickling filter plant utilizing digestion, vacuum filtration, and landfill to dispose of the settled sludge. Studies were conducted to determine the optimum chemicals and dosages for the vacuum filtration of the digested sludge, and to assess the additional cost of filtration of a mixture of digested sludge and water treatment plant sludge. Conditioning with 3% ferric chloride and 13% lime provided the best results in the vacuum filtration tests.

Mahoney, Patrick F. & Duensing, Willard J., "Precoat Vacuum Filtration and Natural-Freeze Dewatering of Alum Sludge", Journal AWWA, Vol. 64, No. 10, Part 1, pp. 665-669, 1972. Summary of Mahoney & Duensing report was also published in American City, Vol. 87, No. 12, p. 42, December 1972, under title "How to dewater--water treatment sludge."

Key Words: Dewatering, Rotary vacuum precoat filtration, Natural freezing

This paper described considerations in a testing program to determine critical parameters to dewater gelatinous aluminum hydroxide sludge economically, EPA provided funds for a pilot facility to: demonstrate the technical feasibility of dewatering alum sludge by rotary vacuum precoat filtration; determine optimum operating conditions; develop plant scale cost estimates; describe the effect of natural freezing on dewatering of dilute and concentrated sludge mixtures; and determine the optimum maximum layer thickness to be frozen. The rotary vacuum precoat filtration operation is described. The variables studied included: sludge solids cake; filter aids; drumspeeds; knife advance rate; filter drum submergence; filter rate; cake moisture; and filtrate quality. Sludge was pumped from the settling basins to a constantly agitated feed tank, then to a filter bowl. A 20# cake solids with filtrate quality <5 JTU was achieved at 5 gal/ft²/hr. The cake can be used as landfill. Polymer conditioning was not beneficial at Albany. Sludge treatment costs are estimated at \$6.05/mg treated water and \$9.25/1000 gal of sludge. A 4' sludge depth was frozen in layers. Good liquid-solids separation was obtained following thawing.

Nebiker, J.H., Sanders, T.G., and Adrian, D.D., "An Investigation of Sludge Dewatering Rates", Journal WPCF, Vol. 41, No. 8, Part 2, pp. R255-R266, August 1969.

Key Words: Sludge treatment, Gravity dewatering, Sludge handling

Sludge handling for primary and secondary treatment total 25-65% of total operating and capital costs. Emphasis should be placed on volume reduction before ultimate disposal. Parameter formulations and laboratory tests are needed for gravity dewatering. Details are provided on previous research. Possible parameters for gravity dewatering are: sludge depth, sludge permeability, final solids content, and character of supporting media. Formulations are presented for determining specific resistance and the coefficient of compressibility. Gravity dewatering experimental apparatus and procedure are also described. Solids content, specific resistance, coefficient of compressibility, and uniformity coefficient data are tabulated for dewatering of mixed digested sludge on sand media. Standard divergence between theoretical and experimental values was 50%. The theoretical formula, verified by experimentation, shows initial solids content, filtrate viscosity, depth, specific resistance, and coefficient of compressibility to be important. Coarse media increase drainage rates but produce more turbid filtrates. Influence of polymers on coefficient of compressibility is needed. This work should be applicable to water treatment wastes, industrial sludge, liquid manure, and benthic deposits.

Kovach, M.P. (with Polkowski, L.B.) "Thickening and Dewatering Properties of Water Treatment Plant Sludges". Thesis presented to Dept. of Civil and Environmental Engineering, University of Wisconsin. p. 43, Fig. 16, Tab. 12, Ref. 19.

Key Words: Water softening, Dewatering, Sludge, Alum sludge, Lime softening sludge, Solids flux concept, Vacuum filtration

Sludge samples from five lime softening and five alum clarification treatment plants in Wisconsin and Minnesota were studied in relation to both their thickening and dewatering properties. The concept of solids flux was applied to the investigation of the thickening properties. Individual batch settling tests on the sludge samples revealed that sludge depth and column diameter, as well as cold storage of samples for prolonged periods, did not affect the initial settling velocity of the sludge interface. Daily variations in thickening properties of lime softening and alum clarification sludges underscored the importance of analyzing numerous samples from a particular plant in order to determine the maximum range and probability relationships for thickening area requirements. Vacuum filtration properties were examined by the Buchner funnel and filter leaf tests. Suspended solids concentration of sludge exerted a significant effect on the specific resistance of most lime softening and lime conditioned alum clarification sludge samples. Lime softening sludges tended to dewater to a higher cake solids concentration and at a greater filtration rate than lime-treated (pH 11.0-11.5) alum clarification sludge samples. Day-to-day variations in dewatering properties occurred for both lime softening and lime-treated alum clarification sludge samples. Lime softening sludge samples generally dewatered to a drier cake concentration and at a greater loading rate than lime-treated alum clarification sludge samples.

Scolari, E., "Reclaiming Water from Water Plant Sludge", Public Works, Vol. 99, No. 6, p. 100, June 1968.

Key Words: Water reuse, Drying beds

This article showed how the recovery of supernatant from sludge drying beds could produce a treated water cost savings. Water treatment included lime-soda softening, clarification, recarbonation, and vacuum type diatomite filtration. Some sludge is recirculated. It was feasible to reclaim the highly treated sludge supernatant rather than discharge this liquid to the sewer system. An asbestos cement lined pipe intercepted decanted water and returned this water to receiving wells by gravity flow. Pumps, automatically operated by float switches, returned this water to the flocculating part of the treatment facilities. Final installed costs were less than \$6526. The first year the plant reclaimed 36 mgd of water with a treated water cost value of \$8394. Second year recovery exceeded 43 mgd with a cost value of \$10,563.

Stoll, B.J., "A Laboratory Study of Water Treatment Sludge Treatment Handling, Conditioning and Dewatering Techniques", Thesis Presented to Department of Civil Engineering, Division of Graduate Studies University of Cincinnati, for Master of Science, 1970, 82 pp.

Key Words: Filtration, Centrifugation, Settling

This study evaluated the settling, filtration, and centrifugation of raw and polyelectrolyte conditioned coagulation sludge from the Cincinnati Water Treatment Plant. Important process parameters were identified and analyzed. Literature was reviewed on the bridging action of polyelectrolytes as conditioning agents and coagulant dosage optimization considering initial sludge solids content, sludge volume filtered, filter surface area and pressure. Sludge sampling and storage procedures, conditioning agent preparation, sludge solids content, and laboratory dewatering analyses are discussed. Data are tabulated and graphed for settling, filtration, and centrifugation tests on raw and polymer conditioned sludge. A cationic polyelectrolyte effectively conditioned sludge for dewatering by filtration or centrifugation. Settling was a good pretreatment method to make sludge amenable to dewatering by filtration and centrifugation. Additional work suggested included: investigation of coagulant dispersion and mixing techniques; pilot filter and centrifugation studies of raw and polymer conditioned sludge.

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WATER TREATMENT PLANT WASTES

Treatment of Sludges

Sludge Conditioning

Doe, P.W., "Use of Polyelectrolytes as a Sludge Conditioner", Paper Presented at the Polyelectrolytes Seminar, Annual AWWA Conference, June 4, 1972, Chicago, Illinois.

Key Words: Polyelectrolytes. Specific resistance, Compressibility index

Raw water quality and treatment processes utilized influence sludge production. Polyelectrolytes have applicability as primary coagulants, coagulant aids, and sludge conditioners. The prime purpose as a conditioner is to prepare thick gelatinous type sludges for disposal. Polymers can strengthen floc particles and aid sludge dewatering. Trial and error selection processes are necessary. A polyelectrolyte sludge conditioner can alter the physical character or thickened sludge. The greatest practical use is pretreatment before filter pressing. A basic filtration equation is presented. Lowering the coefficient of specific resistance and compressibility index increases the process efficiency. Polyelectrolytes help produce a handleable cake that is easily removed from the filter cloth. The article concludes: high molecular weight non-toxic polyelectrolytes must be used in all water filtration plants where supernatant could be returned to the plant inlet; laboratory testing is required; liquid form polymers are more easily and economically handled; and polyelectrolytes help produce a good filter press cake with a less obnoxious filtrate.

Vogh, R.P., Warrington, J.E. & Black, A.P., "Potato Starch as a Sludge Conditioner", Journal AWWA, Vol. 61, No. 6, pp. 276-284, June 1969.

Key Words: Flocculation, Activated silica, Potato starch

Activated silica was used as a flocculant aid to settle softening precipitates at a Florida water treatment plant. Activated silica compacted the sludge to a resistance where torque complications made reactor operation difficult. Jar tests were run using alum, ferric sulfate, cold water starch, anionic polymer, cationic polymer, carboxymethyl cellulose, lignosulfonate, and magnesium sulfate. Cold swelling potato starch proved effective and economical in barrel tests conducted on 55 gallon water samples. Sludge conditioned by potato starch occupied 50% of the settled volume of activated silica sludge. A more turbid water entered the filter from the starch treatment, but did not decrease filter runs. Potato starch eliminated torque in the plant. A 1% feed solution is used. A delivery system is detailed. Potato starch is cheaper than activated silica for Gainesville. An instrument is illustrated and method described to evaluate potential torque considerations. The action of potato starch is described in producing a mobile and soft sludge.

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WATER TREATMENT PLANT WASTES

Treatment of Sludges

Types of Wastes

Albrecht, A.E., "Disposal of Alum Sludges", Journal AWWA, Vol. 64, No. 1, pp. 46-52, Jan. 1972.

Key Words: Flotation, Alum recovery

This study enumerated present disposal methods for purification and softening wastes and investigated four alum sludge treatment procedures. Alum sludge character includes: insolubility in natural pH water; settleability yet not easily concentrated or dewatered; and ability to clog soil when disposed on land. Recycling of supernatant from the sedimentation of filter washwater is suggested. Advantages, disadvantages, and concentration considerations are provided for alum sludge treatment by discharging to surface waters and sanitary sewers, thickening and drying beds, lagooning, filter pressing, vacuum filtration, centrifugation, and freeze-thaw processes. Laboratory investigation and test procedures are explained for alum recovery, flotation and vacuum filtration, and the mixing of alum sludge with raw sewage. The laboratory study effectiveness is discussed. Acidified alum sludge was amenable to dewatering by flotation and vacuum filtration. The study recommended pilot-plant work on alum recovery and mixing of the purification waste with raw sewage.

Neubauer, W.K., "Waste Alum Sludge Treatment", Journal AWWA, Vol. 60, No. 7, pp. 819-825, July 1968.

Key Words: Dewatering, Landfills, Alum sludge

This study evaluated four alum sludge dewatering methods at two water purification facilities. Coagulation waste character includes: chemical precipitates with organic debris, high moisture low solids content, easily settled-difficultly handled, and insolubility in natural water pH. Analyses for total, suspended, volatile-suspended solids concentrations of clarifier sludge were made in accordance with Standard Methods. Some density, BOD, COD, and pH measurements were taken. Performance criteria were based on a 20% total solids content for landfill disposal following conventional settling to reach 1% solids concentration. A Buchner funnel simulated vacuum filtration in the laboratory. Raw sludge and cake solids content, filter loading rate, drying time, liquid viscosity, and operating vacuum were considered. A precoat was needed to achieve 20% solids. Filtrate analysis showed 99% suspended solids, 50% BOD, and 95% COD removed. Bench scale centrifugation and plant size lagooning could not produce a 20% solids concentration. A 20% solids level could be reached by sand drying in 100 hr with a loading rate of 0.8 lb/ft². Filtrate can be recirculated to the treatment plant influent. Capital, operating, and maintenance costs are estimated for vacuum filtration and sand drying. Treatment costs were less than \$5/million gallons of raw water processed.

Young, E.F. "Disposal of Sludge from Sedimentation Plants, with Special Reference to Alum Sludge", Ninth International Water Supply Congress, New York, 1972. (To be published.)

Key Words: Sludge disposal, Water purification, Water treatment, Alum sludge, Dewatering processes

The results of a general questionnaire circulated to member countries (Bulgaria, Denmark, Finland, Hungary, India, Ireland, South Africa, U.K., U.S.A., and U.S.S.R.) disclosed that sludge disposal was a problem to relatively few members. The spread of data covering type of raw water, sedimentation tank, and thickness indicated that sludge quantities and characteristics varied according to the raw-water characteristics and the design and manner of desludging of the sedimentation tanks. The appendix of the report summarized data on sludge quantities, but excludes information from the U.S.A. and Great Britain, in view of the large volume of published data available. The following treatment processes and matters in the reporting countries were briefly reviewed: sedimentation tanks, sludge concentration, concentrator chambers, settlement and thickening tanks, chemical conditioning, sludge lagoons, draining and drying beds, filter pressing, centrifuging, vacuum filters, alum recovery, freezing and thawing, and sludge pumping. Huge quantities of alum sludge in the future will pose problems of disposal in a growing number of nations.

King, P.H., Olver, J.W., Randall, C.W., and Caskey, J.A., "Conditioning and Disposal of Ferric Sulfate Sludges", Presented at Fourth Annual North East Regional Antipollution Conference, Univ. of Rhode Island, Kingston, R.I., 25 pp., 1971.

Key Words: Dewatering, Polyelectrolytes, Filtrability

Synthetic organic polyelectrolytes conditioned ferric sulfate sludges for dewatering by gravity drainage and vacuum filtration. Previous work revealed successful polymer conditioning depended on sludge character, nature of polyelectrolyte used, and the time and manner of polymer addition. Polymers have been able to: decrease specific resistance of sludge; improve alum sludge drainability; be most effective with molecular weights of 1,000,000 or more and when added to sludge following settling; and increase dewatering rates in vacuum filtration or open sand drying beds. 500 ml samples of a ferric sulfate - lime sludge were pH adjusted. Polymer doses of 0-190 ppm were mixed with sludge for 2 minute periods at 100 rpms. This speed kept the system homogeneous and prevented premature settling. Parameters studied were: pH sludge solids concentration, nature and dose of polyelectrolyte, specific resistance of conditioned sludge, zeta potential and drainage rates. Results indicated: synthetic organic polymers improved ferric sulfate sludge dewaterability; optimum pH range was near neutrality; sand bed drying was effective; and no correlation existed between zeta potential and improved filterability. Polymers form chemical bridging mechanisms between floc particles.

Lewandowski, G.A. & Linford, H.B., "Filtration of Ferric Hydroxide", Environmental Science and Technology, Vol. 6, No. 2, pp. 169-172, February 1972.

Key Words: Filtration, Filterability, Ferric Hydroxide

This study showed the influence of five process variables on the filterability of ferric hydroxide precipitate. These parameters included: final pH; type of base used to precipitate the iron; rate of base addition; rate of sample agitation; and the iron concentration. Surface charge of the ferric hydroxide suspension was measured using a streaming potential technique. The surface charge was correlated with filtration rates. The apparatus and filtering method were described. Illustrations are provided of the streaming potential cell and apparatus, and the filtration equipment. The rate of base addition and sample agitation had negligible effect on the filtration time except when $\text{Ca}(\text{OH})_2$ was used as the precipitating base. Optimum pH range was 6.5-7.5 with NaOH and KOH as the best precipitating bases. High iron concentrations improved filterability.

Campion, H.T., "Lime Sludge and Its Disposal", Journal AWWA, Vol. 26, No. 4, pp. 488-494, April 1934.

Key Words: Sludge treatment, Lime sludge, Disposal methods

The build-up of sludge deposits resulted from intermittent dumping of lime sludge to the Grand River. Complaints on river pollution were received. Continuous sludge removal equipment for waste dilution was expensive. Five hundred tons of sludge could be handled at the sewage treatment plant at extra cost. Plant modifications accompanied new sludge removal equipment. Disposal methods proposed included: transport to fill or ponding reclamation; partial or complete drying for use as soil sweetener; calcining and reuse; and use in paints, putty, wall board, etc. Sludge beds could reduce moisture to 50%. Automatic vacuum filtration was relatively inexpensive and could reduce moisture to 60%. Final drying could be accomplished in a rotary drier or Nichols Herreschoff furnace. Farm use of dried lime is possible. A laboratory calcining test was run. After 5 burnings and recycling of calcined lime, magnesium content increased. Lime purity was below local specifications. Some success was reported in using dried lime for plaster and insulating board manufacture. The final plan was to locally dry and bag sufficient sludge and compete with limestone now used. Demonstrations would be arranged and the product advertised.

Howson, L.R., "Lagoon Disposal of Lime Sludge", Journal AWWA, Vol. 53, No. 9, pp. 1169-1173, September 1961.

Key Words: Lagoons, Lime sludge

This study evaluated variables to be considered in the design of lime sludge lagoons. One case showed that lime sludge discharged to a sewage treatment plant accumulated in the Imhoff tanks, affecting plant efficiency and capacity to handle sewage wastes. Softening wastes vary in character and density. Volume is inversely proportional to the solids concentration. Lagoon storage capacity is influenced by: sludge volume, continuous or intermittent operation, supernatant decantation, and air drying. Cost data is presented for pumping lime sludge in asbestos-lined cement pipe. Pumping sludge to lagoons is an economical treatment where land is available. A 50% moisture content can be achieved in well operated multiple lagoons with decantation facilities and air drying. Sludge volumes can be reduced to 16% of original volume. A loading rate of 0.5-1.0 acre-ft/yr/mgd/100ppm hardness removed is suggested to reach a 50% moisture content in one year. Multiple lagoons, at least three, must be operated on a fill and let dry basis with filling at one end and decantation at the other. The water level should be low to facilitate sludge compaction.

Judkins, J.F. & Wynne, R.H., "Crystal-Seed Conditioning of Lime-Softening Sludge", Journal AWWA, Vol. 64, No. 5, pp. 306-309, May 1972.

Key Words: Water treatment, Filterability, Settleability, Crystal-seeding

This report determined the filterability of sludge produced by softening laboratory-hardened water and investigated the effect of crystal-seeding on the settleability and filterability of this sludge. The methodologies of synthesizing the hard water and performing jar tests and settleability and filterability evaluations are described. Important variables are: crystal-seed dosage; mixing rate; and return-sludge recycle. Sludge filterability was measured by the specific resistance and settleability was made by the sludge volume index. A 200 rpm mixing rate was optimum in reducing specific resistance and a 300 rpm rate optimum in reducing the sludge volume index. A 50% return-sludge dosage improved filterability while a 25% return was best for improving settleability. Recycling was beneficial. The sludge produced ranged from $4.38-41.9 \times 10^{10}$ m/kg in specific resistance.

Spaulding, C.H., "Conditioning of Water Softening Precipitates", Journal AWWA, Vol. 29, No. 11, pp. 1697-1707, November 1937.

Key Words: Water softening, Conditioning

This study showed a process modification to conventional coagulation that could reduce floc carryover to the filters. A softening precipitator was constructed to produce soft water and agglomerate small particles into larger coagulated masses that are more easily filterable. Experience with sludge return showed tastes and odors were imparted and a fine hard to remove turbidity resulted. Laboratory and plant scale precipitator mixing and settling equipment are described. Plant tests were run on modified and conventional units. The precipitator was ten times more efficient than the conventional basin. Formulae developed for precipitator diameter and height were modified to meet excessive depth limitations. This reactor is new in that it supports precipitates in the settling compartment by means of vertical velocities. The precipitator sludge is concentrated to 5-15% in thickeners and supernatant water is returned to the raw water well. Physical and chemical data are presented for 6 months operation. Water from the precipitators to the filters is generally less than 1 ppm turbidity and is filtered rapidly.

Adrian, D.D. & Nebiker, J.H., "Source Control of Water Treatment Waste Solids". Progress Report for Federal Water Pollution Control Administration, WP-01239-02, 95 pp., March 1969.

Key Words: Dewatering, Sludge treatment, Drying beds

The purpose of this report was the development of rational design formulations for engineers to design dewatering and drying beds for water treatment sludges. Work is prepared on dewatering by freeze-thaw and filter pressing procedures. Differential equations for the reaction kinetics of sludge drying are prepared. Curves included: drying rate, weight, and free moisture content versus time; evaporation ratio versus moisture content; drying rate versus moisture content; critical moisture content versus drying solids per area; free moisture content versus time; and log drying rate versus log free moisture content for alum sludges. A mathematical model for drying and gravity drainage is constructed with initial and boundary conditions. Curves of applied depth versus duration and total annual costs versus applied depth are shown for different specific sludge resistances. An objective function is made to optimize dewatering costs. Specific resistance and coefficient of compressibility are studied for freeze-thaw tests. Concentrated sludge cakes frozen and thawed showed a cake structure breakdown to a watery nature with crystalline solids that settle readily. An appendix provided definitions of wastewater treatment sludge disposal terms.

Barnhill, K.G., "Sludge Disposal Alternative", 31st International Water Conference of the Engineers Society of Western Pennsylvania, October 27-29, 1970.

Key Words: Sludge, Equipment, Costs

As more primary and secondary wastewater treatment plants are built, more sludge will be generated, and there will be more pressure to find an optimum disposal method. The optimization would of necessity consider: (1) Availability of prior applicable experience, both in reference to quantity and to type of sludge. (2) Equipment operation, degree of complexity, need for standby units, dependability, manpower requirements, operator skill required, controls, and hazards. (3) Costs, including capital, operating, and associated allied costs (hauling and ash disposal). (4) Implementation problems, including air pollution, odors, ash disposal, pretreatment (degree of dewatering), need for auxiliary fuels, other environmental effects. (5) Regulatory and user attitudes, including present and future air and water pollution requirements and directions.

Burd, R.S., "23. Water Plant Sludge Disposal. A Study of Sludge Handling and Disposal", FWPCA Contract No. PH 86-66-32, pp. 476-485, June 1966.

Key Words: Sludge treatment, Purification wastes, Softening wastes

Treatment of water utility wastes has become important due to urbanization, unavailability of cheap land, and public awareness of pollution. Purification sludge is mostly inorganic with few odors. Softening wastes are principally calcium carbonate with small ferric, magnesium, and aluminum hydroxide precipitates. 2.5 lbs. of dry sludge is produced per pound of commercial CaO. Solids concentrations vary from 5-33% with total volume 0.4-6% of total water treated. Dilution of waste into rivers produces turbidity and forms sludge banks. Lagoon capacities are effected by sludge solids concentrations, continuous or intermittent loading, supernatant decantation, and climate. Costs are given for pipeline transport to lagoons and for lime calcining processes. Sand drying beds and vacuum filters are useful. Dried sludge has been used for soil conditioning and roadway base stabilization. Alum recovery and lime recovery are suggested solutions to alleviating the magnitude of the sludge disposal problem.

Doe, P.W., "Water Plant Sludge Treatment", Paper Presented at Ohio Water Pollution Control Conference, Sheraton Hotel, Columbus, June 29-July 1, 1971.

Key Words: Dewatering, Water plant sludge treatment, Artificial freezing, Filter pressing

Wastes from water treatment facilities vary in composition with the quality of the supply source. Wastes from coagulation, flocculation, sedimentation, and filter backwashing processes are affected by flow and seasonal changes. Sludge characterization of wastes generated from reservoir, river, and groundwater supplies is provided. The advantages and disadvantages of dewatering by pre-thickening, lagooning, artificial and natural freezing, vacuum-filtration and filter pressing are presented. The AWWA Research Foundation is mentioned as a central clearing-house for new or improved sludge treatment technology. Reference is made to the artificial freezing of alum sludge at the Hodder Works. Polymer is fed to condition the waste before thickening. Thickened sludge is stored and transported to freezing molds. The thawed sludge is pumped to lagoons for liquid-solid separation. Cost, power, and construction considerations are provided. The Little Falls Plant plans to filter alum sludge from sedimentation basins and filter backwashing. Laboratory and pilot tests were conducted to evaluate design parameters. The presses utilize a precoat, lime, and polymers for conditioning. Two presses can produce 50 tons of cake per 8 hour operation. The cake can be used as landfill.

King, P.H., Bugg, H.M., Oliver, J.W. & Argo, D.G., "Treatment of Waste Sludges from Water Purification Plants", Bulletin 52 of the Virginia Polytechnic Institute and State University, Blacksburg, Water Resources Research Center, Sept. 1972 49 pp., 19 fig, 3 tab, 18 ref.

Key Words: Sludge disposal, Water purification, Water treatment, Sludge treatment

The freezing and thawing process, as well as polyelectrolyte conditioning agents, rapidly dewatered alum and ferric sludges collected from two water plants and lime sludges from two wastewater treatment plants in Virginia. Sludge filterability and drainability were evaluated by means of a Buchner funnel apparatus and the concomitant specific resistance tests which enabled the determination of the correct pH, time of agitation, and effects of temperature and solids concentration on the optimum dosage of polyelectrolytes. Selection of an appropriate polymer was related to a number of factors, including primary coagulant and system pH. Optimum dosage of the 6 anionic, 4 cationic, and 5 nonionic polyelectrolytes tested (products of 4 manufacturers) was directly related to sludge solids concentration. Dewatering of polymer conditioned sludges was accomplished by bench-scale sand beds and vacuum filtration. Although alum sludge was relatively more difficult to dewater than sludge produced by iron salts, polymer conditioning of alum sludge improved and diminished this difference. Anionic polymers were effective conditioning agents for lime clarification sludges, and also proved somewhat superior to nonionic agents and significantly better than cationic chemicals for alum and ferric salt sludges.

Werts C.F., "Sludge Removal and Disposal", International Water Supply Congress & Exhibition, Stockholm, Sweden, 1964, 14 pp.

Key Words: Sludge disposal, Disposal methods

This report reviewed water treatment plant sludge disposal methods and referenced each technique to individual water utilities. Purification and softening waste characteristics are discussed. Sludge production is related to the physical character of the solid material and the present solids in the wet sludge. Pilot testing on raw water is recommended to determine the amount and type of sludge for lagooning or recalcining. The 48 State Sanitary Engineers were surveyed. They reported disposal by discharge to watercourses, lagooning, thickening, recalcining, and alum recovery. Data are provided at different facilities for each operation. Magnesium hydroxide can be eliminated from softening waste prior to calcining by carbonation or selective softening procedures. The report concluded: discharges to watercourses would be discontinued; lagoons and drying beds require careful design; supernatant must be withdrawn from lagoons; and a method to separate turbidity from CaCO_3 sludge must be developed before some utilities can recalcine.

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WATER TREATMENT PLANT WASTES

Treatment of Sludges

Miscellaneous Processes

Davis, Stewart; "Alternatives For Phosphate Removal". Water & Sewage Works, Vol. 117, p. 336, October 1970.

Key Words: Water quality control, Tube settlers, Mixed-media filter

Micro FLOC has developed a tertiary treatment process that can effectively remove orthophosphates and polyphosphates by chemical precipitation. Domestic wastewater phosphorus has been reduced to 0.5mg/l P using lime dosages of 200 to 500 mg/l CaO or alum dosages of 90 to 200 mg/l. The process combines flocculation, modular tube settlers, and mixed media filtration. Units range in size from 20 gpm to 200 gpm. Four 200 gpm units, requiring less detention time than conventional treatment systems, are being planned for Ocean Pines, Maryland. A Micro FLOC installation at Shagawa Lake has reduced effluent from 5.6 mg/l to 0.05 mg/l (PO_4 as P) using 145 mg/l alum. Similar advanced treatment processes as Battelle Northwest's 100,000 gpd trailer mounted system and a 280,000 gpd at Taulatin, Oregon are mentioned. A reference is also made to Lake Tahoe's lime coagulation system and recalcination operation.

Haywood, R.W., "Basic Data for Chemical Waste Disposal", Sewage and Industrial Waste, Vol. 30, No. 9, pp. 1156-1159, September 1958.

Key Words: Basic data collections, Chemical wastes, Waste characteristics

The purpose of this paper was to discuss benefits derived from early recognition and study of waste disposal problems and describe difficulties in obtaining basic data for evaluating disposal requirements. No generalizations are usually possible for highly variable, complex, organic-inorganic chemical wastes. Control may be achieved through product substitution or process modification. Product substitution examples lowering treatment requirements include: plastic for starch in the textile industry; mineral acid for organic acid; and process applications producing a filterable insoluble salt rather than highly soluble one. A systems approach should be applied to processes to minimize the cost of production plus waste treatment. Several physical-chemical waste characteristics are enumerated. Testing complications for BOD analysis and seed preparation are detailed. Adequacy of testing laboratories must be considered. Toxicological studies should include fish kill effects and food chain destruction. The size or volume, type (flowing, impounded, tidal), and present and future use of receiving waters are important. For adequate dilution, the shape, quantity, velocity, turbulence, salinity, and thermal stratification of watercourses need study.

Mogelniki, S.J., "Experiences in Polymer Applications to Several Solids-Liquids Separation Processes", Proceedings Tenth Annual Sanitary Engineering Conference, Waste Disposal from Water and Wastewater Treatment Processes, University of Illinois, Urbana, pp. 47-62, February 6-7, 1968.

Key Words: Polymers, Dewatering, Primary flocculants, Flocculant aids, Filter aids, Sludge aids, Sludge conditioning

This paper cited the early utility of polymers in the mining, metal, and paper industries and tabulated data on the effectiveness of synthetic, organic, high molecular weight, water soluble polymers to separate solids in industry. The polymers depend on adsorption, charge neutralization, and inter-particle bridging to agglomerate small colloidal suspensions into larger colonies. Typical cationic polyamine, anionic, and nonionic polymer formulae are prepared. Polymers function as primary flocculants, flocculant aids, filter aids, and sludge conditioning agents. Data are tabulated for polymer application in sedimentation, flotation, filtration, and centrifugation processes. Wastewater clarification with polymer addition is shown on aluminum industry effluent, steel mill flue dust, electroplating streams, tannery waste, steel mill scale, and raw sewage flocculation at an activated sludge and trickling filter plant. Flotation data are prepared for brewery, vegetable oil processing, meat packing, waste activated sludge and petroleum refinery wastes. Data are presented for sand bed drying and vacuum filtration of textile industry, elutriated digested primary, and primary-secondary elutriated digested wastes. Centrifugation studies were conducted on chemical and sewage sludges. Polymer advantages include: reduced handling and chemical storage; easily controlled dose levels; increased suspended solids capture; higher hydraulic capacity; and reduced costs.

Nemerow, N.L., "Cooperative Treatment of Industrial Wastes", Industrial Water Engineering, Vol. 6, No. 6, pp. 30-32, June 1969.

Key Words: Industrial wastes, Municipal wastes, Separate treatment, Combined treatment

This article proposed the consideration of several art and science factors for joint treatment of combined industrial and municipal wastes. The art factors included: precedent of separate or combined treatment; relation of industry to community; political compatibility of industrial and municipal officials; sewer charge rates; industrial proximity to sewage treatment plant; competence of sewage treatment personnel to handle the waste and avoid major upsets; and the permanence of industrial waste production in type and quantity. The science factors included: the type of sewage plant and its ability to remove the industrial contaminants; the industrial waste character and parameters such as k value, deoxygenation rate, ultimate oxygen demand, toxic chemicals and metals, temperature, grease content, refractory organic matter, phosphates, nitrates, and other algal nutrients; industrial effluent quality and effect on quality of receiving stream; and the economic alternatives available.

DISPOSAL METHODS

Brine Wastes

Day, M.E., et al, "Brine Disposal Pond Material", Research and Development Progress Report No. 588, Contract No. 14-01-0001-1306, Work Order No. 3, August 1970. 134 pp.

Brine disposal, Ponds, Design considerations, Cost estimates

This report is designed to present new information on the disposal of brines from saline water conversion processes and the associated costs. Information is presented on: design considerations for disposal ponds; design criteria and cost estimates; operation and maintenance considerations and costs; methods to control seepage of concentrated brine solutions into aquifers; construction of various holding ponds; and detailed specifications for earthwork, buried linings, hard-surface linings, and earth linings. Appendices include material on: summary of state regulations on brine disposal; bibliography; computer analysis of brine disposal ponds; glossary; and conversion factors for British to metric units of measure

Haney, P.D., "Brine Disposal from Sodium Zeolite Softeners", Journal AWWA, Vol. 39, No. 12, pp. 1215-1219, December 1947.

Key Words: Brine disposal, Sodium zeolite softeners, Controlled dilution

The waste from sodium zeolite softeners contains waste products of regeneration plus unused salt. The brine is principally composed of chlorides of calcium and magnesium, together with small amounts of various iron and manganese compounds. Usually 5-10% of the treated water is needed for regeneration. Salt requirements are 0.4-0.5 pounds/1000 grains hardness removed. Limiting USPHS potable water standards are: magnesium < 125 ppm; chloride < 250 ppm; and total solids < 1000 ppm tolerable. Brine discharges to sanitary sewers can corrode pumping equipment, force mains, and upset biological processes. Discharge to streams can kill fish and injure livestock. Evaporation ponds sometimes barely exceed rainfall rates, leave salt residues, and contaminate groundwater or streams by seepage. Controlled dilution requires storage reservoir and release mechanism costs. Brine disposal wells may require pretreatment to prevent suspended matter from plugging the pores of the receiving formation. Costs/foot of well are outlined. Brine must be conditioned not to react with receiving formation matter to produce precipitation. Controlled dilution appears most applicable.

DISPOSAL METHODS

Subsurface

AWWA Committee, "Findings and Recommendations on Underground Waste Disposal", Journal AWWA, Vol. 43, No. 12, pp. 1295-1297, December 1953.

Key Words: Water pollution, Industrial waste disposal

This article enumerated considerations for industrial waste disposal on underground sources. Findings include: nationwide scope of industrial groundwater pollution; waste types as natural-artificial brines, phenolic compounds, heavy metal salts, cleaning fluids, picric acid, gasoline-petroleum products, pickling liquors, fruit and vegetable cannery wastes, milk wheys, and cooling water; pollutant flow is smooth and laminar with velocities of inches or feet/day; hydraulic gradients influence route and flow times; industrial water requirements are growing; groundwater disposal is attractive; and some wastes are toxic. Conclusions show geologists must appraise aquifer contamination, preventive pollution measures are needed, legal considerations are required, and groundwater will provide future needs. The report recommends: identification of areas where groundwater disposal is not possible; permit systems for agencies to control industrial wastes; and provisions for recourse to courts, if needed, to end industrial underground waste disposal.

AWWA Committee, "Underground Disposal and Control", Journal AWWA, Vol. 49, No. 10, pp. 1334-1342, November 1957.

Key Words: Waste disposal, Underground pollution

This article cites examples of underground pollution problems and presents survey analysis of U.S. underground disposal practices. These examples include: well screen corrosion due to acid waste percolation in an estuarine swamp; cadmium and hexavalent chromium contamination of groundwater by aircraft waste discharged to leaching pits; and calcium chloride contamination of downstream wells by surface discharge of this concentrated waste. Survey information is provided on contaminant types, waste constituents, waste sources, and statutory control in the U.S. A tabulation is made of the nature of specific pollutants and observed distance and time of travel. A recommendation is made to group states with similar control characteristics for common studies of existing problems and determination of trends. Factors to estimate potential groundwater pollution are: gaging of industrial growth rate-adequacy of existent waste facilities and future needs; urban or suburban expansion developments to provide industrial growth; available water sources and comparative use of waters; general geologic and hydrologic conditions governing underground contaminant movement; and knowledge of existing statutory controls.

AWWA Committee, "Underground Waste Disposal and Ground Water Contamination", Journal AWWA, Vol. 52, No. 5, pp. 619-622, May 1960.

Key Words: Water quality, Subsurface discharge

This article considers the development of quality parameters to detect ground water contamination. Suitable trace constituent selection is complex. Difficulties arise since: the elements must be in natural water-soluble compounds; concentration determination must be simple and inexpensive; the elements must be common in most natural groundwaters and in the probable liquid-waste contaminant; and the elemental compounds must be stable. The amortization cost of industrial surface waste disposal over plant life usually indicates a savings over most injection or subsurface discharge techniques. Rigid statutory standards are needed for disposal well construction and ground formation selection. Pretreatment may be required. Ground-surface disposal is generally by ponding and spraying or ditch-spreading application to large land areas. Ground-surface disposal contaminates when the waste application rate is in excess of evaporation-transpiration requirements of vegetal cover. Synthetic detergent flow times are a function of distance, pumping rate, and area geology. Standards need development to evaluate disposal techniques and detect unsatisfactory disposal practices.

Billings, N., "Ground-Water Pollution in Michigan", Sewage and Industrial Wastes, Vol. 22, No. 12, pp. 1596-1600, December 1950.

Key Words: Groundwater, Waste disposal, Flow direction, Waste toxicity, Time response

This report provided some considerations on the effect of pollutant infiltration into ground-water reservoirs. Where groundwater recharge is important, waste penetration into the soil may be harmful. Examples of time responses for contaminated groundwaters are prepared for plating, picric acid, phenolic, salt, gasoline, cheese factory, and septic dry well wastes. Subsurface flows are difficult to predict. Influencing factors include: hydraulic gradient; high-capacity water wells; drainage ditches; local cloudbursts; and dam construction. Major considerations with waste disposal on the ground are enumerated. They are: waste toxicity; soil conditions and geology; effect of waste on groundwater; and flow direction of waste. Pumping tests provide some criteria and help establish liability in cases of well contamination. Legal restrictions are being formulated to consider waste disposal effect on underground resources endangering a neighbor's welfare. Close regulation is needed to conserve water resources for this and future generations.

Black, W.B., "Underground Waste Disposal", Sewage and Industrial Waste, Vol. 30, No. 5, pp. 669-672, May 1950.

Key Words: Deep wells, Industrial wastes, Rock strata

This paper discussed the injection of industrial wastes into deep wells. Porous sandstone formations in Michigan are satisfactory for industrial waste disposal. States have allowed oil refineries, chemical plants, and pharmaceutical plants to use these strata for pumping inorganic and organic industrial wastes. Rock strata testing is urged to measure waste control, prevent contamination of fresh water, and study effect on surroundings. Testing steps include: Fact-finding study of the industrial plant waste; study of underground formation; laboratory compatibility of reaction between waste and receiving strata; drilling of test wells to determine possible reservoirs and barrier effectiveness; and capacity, injection rate, and flow character of wastes. These data give daily capacity, pump pressures needed, extent of waste travel, and safety factors. Systems economics, construction cost, daily maintenance, and depreciation cost can be estimated. Fracturing techniques give an estimated 40 million gallon/acre total storage capacity. Cost data are given. Potential underground uses are: radioactive wastes; municipal sewage effluent; and fresh water storage.

Caswell, C.A., "Underground Waste Disposal: Concepts and Misconceptions", Environmental Science & Technology, Vol. 4, No. 8, pp. 642-647, August 1970.

Underground storage, Underground waste disposal

This article illustrates overall aspects of subsurface disposal considerations. Advantages of underground disposal include: ultimate disposal of untreatable wastes from immediate environment; salt water barrier created; storage in arid areas; groundwater recharge; solids storage and disposal; and potential air pollutant storage. Disadvantages include: presence of unfavorable receivable formations; fluid incompatibility; loss of waste control; and legal liability. Surface and sub-surface factors of well design are described. A hypothetical migration rate of fluid example is given. Fluid flow is affected by: permeability; pore geometry; bottom hole pressure; hydrologic conditions; saturation percentage; and damage to formation face. Misconceptions in water injection and salt water disposal wells are explained. Mechanical factors in fluid migration include: formation cementation and porosity; lateral effective permeability and porosity; overlying and underlying beds; fault presence of fracture patterns; earthquake occurrence; fresh-salt water contact levels; structural attitude and hydrologic character of injection formation; and casing effectiveness and cementing program.

Cleary, E.J., and Warner, D.L., "Some Considerations in Underground Wastewater Disposal", Journal AWWA, Vol. 62, No. 8, pp. 489-498, August 1970

Key Words: Deep well pumping, Underground injection

This study outlined public policy, legislative and legal aspects, and administrative guidelines and evaluation criteria for deep well injection of liquid wastes. Industrial wastes being injected include: alkalies, acids, chromates, nitrates, phosphates, sulfites, alcohols, ketones, phenols, cyanides, chlorinated hydrocarbons, and radioactive materials. A national registry could collect and disseminate useful data on underground strata for various wastewaters and provide an expanding body of experience. The effects of long term waste storage, degradation of potential underground resources, and ability of agencies to evaluate injection proposals require study. Case histories are given. Specific legislation exists in Ohio, West Virginia, and Texas. Ohio and West Virginia regulations are discussed with New York policy. A newly created government agency might name suitable injection zones and maintain quantity and quality physical-chemical waste injection data. Legal liabilities and constraints are discussed. Decisions and requirements will be ultimately based on: wastewater characteristics; geology and subsurface hydrology; well construction and testing methods; surface and standby facilities, construction materials; operational practices; and abandonment procedures. The ORSANCO commissioners should create an ad hoc committee to develop public policy guidelines, regulatory procedures, and evaluation criteria for underground injection.

Grubbs, D.M., Haynes, C.D., and Tucker, W.E., "Conservation of Fresh-Water Resources by Deep-Well Disposal of Liquid Wastes", Publication Partially Funded by OWRR, USDI, under Water Resources Research Act of 1964, 85 pps., 1970.

Key Words: Liquid wastes, Deep-well disposal, Subsurface disposal

This study reported that under controlled conditions deep-well injection of liquid wastes can be accomplished in some of Alabama's geologic formations without contaminating fresh-water supplies. Legal implication of this disposal require further definition. General physical parameters explored included subsurface disposal history, geologic requirements, porosity and permeability criteria, ground water fluids, sedimentary rock type and geometry, evaporites, reservoirs, and confining rocks. Fluid mechanics, reservoir mechanics, and pressure relationships are discussed. Specific sites in Alabama are studied and the feasibility of deep-well disposal considered. An appendix contained cost and design data generated by a computer program. Data include capital outlay, operating and maintenance costs. Another appendix treated major chemical reactions between an acid industrial waste, the waters of the receiving formation, and minerals in Alabama's aquifers. Rock reservoirs are laboratory tested to establish storage capacity, flow parameters, and compatibility of receptive layers with the waste. A final appendix discussed stratigraphy and physiography of Alabama.

Le Grand, "Role of Ground Water Contamination in Water Management", Journal AWWA, Vol. 59, No. 5, pp. 557-565, May 1967.

Key Words: Water Pollution, Quality deterioration

The purpose of this article is to place groundwater contamination and its complement in perspective with water development and demonstrate its importance in long-range integrated plans. Geographically distinct areas include: urban area encompassing a municipality and beyond centralized water and sewer service, and rural areas with individual water-waste treatment units. Ground water contamination is influenced by disposal practices; artificial recharge of aquifers, accidents, and salt water intrusion. A major objective is to maintain good health practices and minimize disposal costs. Variable factors for pollution are: variety of waste material; wide toxicity range; man's disposal patterns and accidental releases; subsurface water development; elemental behavior in soil, water, and rock environment; and spatial and temporal criteria. Balanced surface and groundwater development and waste disposal policies are needed with a broad understanding. Other considerations, and land and stream classifications are outlined. An inventory should be compiled of type and quantity of groundwater contaminants and behavior. Work must be coordinated with specific elemental effect on biota studied.

McLean, D.D., "Subsurface Disposal: Precautionary Measures", Industrial Water Engineering, Vol. 6, No. 8, pp. 20-22, August 1969.

Key Words: Injection wells, Subsurface disposal

This study reviewed the characteristics of sedimentary rock receiving formations of liquid wastes, and equations developed by the petroleum industry to measure important disposal well parameters. Desirable characteristics included: uniform sandstone, limestone, dolomite, or fractured shale, large areal extent; sufficient thickness; high porosity and permeability; adequate overlaying and underlaying of impermeable strata or aquicludes; low pressure; below and separated from fresh water horizons; salt - water filled formation; artesian in nature; strata compatible with injected fluids; and no unplugged wells can penetrate the formation in the vicinity. The petroleum industry has developed predictive equations for injection rates and pressures. However, testing is needed. The drilling and testing of disposal wells require: protection of fresh water sources and minerals; injection tests; injection of wastes compatible with receiving reservoir; and monitoring of injection pressure and rate, effluent chemical composition, annulus pressure, and injectivity index (input rate/bottom hole pressure). Further research is required in hydrology waste chemistry, and efficient operation of subsurface disposal systems. Present predictive equations are good when the aquifer is homogeneous and the reservoirs unlimited.

Miller, S.M., "Injection Wells Pose a Potential Threat", Environmental Science & Technology, Vol. 6, No. 2, pp. 120-122, February 1972.

Key Words: Injection, Deep-well disposal

The study presented technical and legislative criteria for the disposal of liquid waste by deep-well injection. More than 200 industrial waste wells are in operation. No federal regulations bind these operations and few states have considered this problem individually. The adequacy of injection to solve fluid waste problems and the need for public, local, state, and federal controls in questions. Subsurface areas can temporarily store reclaimable fluids or permanently store unreclaimable material. Injection theories are oversimplified or complex. Predictive mathematical equations are based on microscopic scale studies. EPA neither opposes nor promotes deep-well injection. Wastes untreatable by alternate methods may be injected. Four states have specific injection laws. Texas requires treatability studies, a list of adjacent landowners, and a technical report to include geologic, waste, and well construction data. Specific effects of well injection operations are enumerated. A series of earthquakes in Denver during the 1960's were a function of well injection and time.

Wright, J.L., "Underground Waste Disposal", Industrial Water Engineering, Vol. 6, No. 5, pp. 24-27, May 1, 69.

Key Words: Liquid wastes, Well disposal

The author stated deep well disposal of liquid waste is technically and economically effective in areas with extensive porous rock formations and with allowable laws. Design requirements included: waste confinement to geologic formation selected for disposal; knowledge of injectivity and storage capacity of disposal zone; physical-chemical waste character analysis; and waste compatibility with the receiving formation. Acids, steel mill picking liquors, toxic organic chemicals, caustics, brines, phenols, sulfides, chromates, cyanides, and radioactive materials have been injected. Storage, treatment, filtration area, injection pumping, and monitoring of liquid waste are essential. The underground formations of the Great Lake region, Mid-Continent, and Gulf Coast areas are described. A tabulation of construction costs for disposal wells is made based on pumping an equal volume of non-corrosive filtered waste into a 500 foot deep well. Installation and operating costs are tabulated. An economic comparison is made of well disposal versus surface treatment systems.

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SECTION VIII

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